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Donna Creek Forestry/Biodiversity Project: Breeding Bird Point Counts 1995 and 1996

L. W. Gyug
1997

PFWWCP Report No. 129

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ABSTRACT

Breeding bird surveys were conducted in 1995 and 1996 as part of the Donna Creek Forestry/Biodiversity Project in the ESSFmv3 240 km north of Prince George B.C. The aim of the project is to develop and test alternative timber-harvesting techniques designed to benefit tree-cavity-nesting birds and mammals. Each of three clearcuts of ± 100 ha were divided into four treatment units: one with stubs (3-m tall stumps at 8-10/ha), one with tree islands (0.18-0.40 ha tree patches occupying 3.3-4.7% of clearcut area), one with stubs and tree islands, and one with neither stubs nor tree islands. This 2x2 randomized-block ANOVA design determined stub effects and tree island effects within clearcuts on breeding bird densities. Concurrent sampling within three adjacent old-growth forests and three nearby clearcuts allowed comparisons of overall bird detection densities within experimental treatments, and of bird densities within tree islands alone, to control forests and clearcuts. Breeding birds were sampled by 50-m fixed-radius point counts from May 22 to June 26, 1995, and from May 29 to July 4, 1996.

Significantly greater densities of yellow-rumped warblers were found within clearcuts where stubs were present. Mountain bluebird densities were significantly correlated with stub densities only when areas without stubs were included in the correlations. Black-backed woodpecker densities were also correlated with stub densities on a point-by-point basis over the range of stub densities that occurred (2-15/ha). The presence of stubs did not increase species richness significantly (average 16% increase). Stub suitability for secondary cavity-nesting species such as tree swallows and mountain bluebirds will depend (at least in part) on hole creation by primary cavity-nesting species, so that higher stub densities that encourage use by woodpeckers are essential.

When bird densities were considered within entire treatment units, tree islands had significant effects for only a few species (yellow-rumped warblers and Swainson's thrushes in both years, and Wilson's warbler in 1996 only) because the tree islands occupied such small percentages of the treatment units in which they were present. However, when densities in just the tree islands were examined, then the densities of seven bird species as well as total bird densities were significantly greater in the tree islands than in the control clearcuts. The presence of tree islands increased species richness by 8.9 species over a clearcut without tree islands (66% increase). However, the average species richness of clearcuts even with tree islands was still 4.5 species lower than in Old-Growth Control forests. It appeared that small tree islands of 0.18-0.40 ha will be unsuitable for establishment of breeding territories for 15 of the 19 common forest bird species in the study area, and that larger tree islands or other mitigative measures will have to be considered for these species.

Both small tree islands and isolated stubs in clearcuts will be used by some cavity-nesting species for both nesting and foraging, and they appear to be essential for nesting of some species within clearcuts. Both techniques can be used, at least partially and for some species, to mitigate the adverse impacts from the loss of wildlife trees during clearcutting. Larger tree islands (on the order of 2 ha or greater) and higher densities of stubs (15/ha or greater) will probably provide better mitigation than smaller tree islands and lower stub densities.

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1.0 INTRODUCTION

The Donna Creek Forestry/Biodiversity Project was initiated in 1990 as a cooperative venture of the Peace/Williston Fish and Wildlife Compensation Program and Fletcher Challenge Canada Ltd (now TimberWest Forest Ltd.). The aim of the project is to develop and test alternative timber-harvesting techniques designed to benefit tree-cavity-nesting birds and mammals. Animals that nest or roost in tree cavities are at some risk in the managed forest because Worker's Compensation Board regulations prohibit the maintenance of any standing diseased or dead trees taller than 3 m on worksites (Backhouse 1993). This project was designed to test whether creating 3-m high stumps (stubs) and retaining small residual tree islands during clearcutting would benefit cavity-using animals. Annual and other reports detailing the initiation and first phases of this project are available (Dawson et al. 1992, Wood 1992, Wood 1994, Wood 1995).

Preliminary breeding bird sampling began at the Donna Creek study sites in 1993 (Gyug and Summers 1995). After analysis and interpretation of this preliminary data, Gyug and Summers (1995) made recommendations to increase the efficiency and accuracy of sampling by replacing the initial transect sampling method used in 1993 with a point-count method for subsequent years. The breeding bird point count results for May-June 1995 were reported under separate cover (Gyug 1996) but these results are re-analyzed here to be included with the May-June 1996 results. The results from the two consecutive seasons (i.e., May-June of 1995, and May-June of 1996) are fully reported here so that Gyug (1996) should only be considered as preliminary results from the first year of a two-year project. Cavity-nesting birds were the focus group for this study since these alternative harvesting techniques have been proposed to mitigate the effects of clearcutting on them in particular, but data was also collected and analyzed for other breeding passerines.

1.1 OBJECTIVES

The overall objective of this portion of the Donna Creek Forestry/Biodiversity Project was to determine the effects of two alternative timber-harvesting techniques, the retention of residual tree islands and the creation of 3-m stubs during clearcutting, on breeding bird densities in the moist, very cold variant of the Engelmann Spruce-Subalpine Fir biogeoclimatic zone (ESSFmv3). The following specific objectives were set for the 1995 and 1996 breeding bird point count sampling and data analysis:

- to determine the effects of stubs and tree islands on relative breeding bird densities within clearcuts using a 2-factor Analysis-of-Variance experimental design,
- to determine the effectiveness of stubs and tree islands in mitigating the effects of clearcutting on forest bird species by contrasting relative breeding bird densities in the treatment areas to old-growth control forests, and
- to determine whether breeding bird densities differed in tree islands compared to clearcut controls and old-growth control forests.

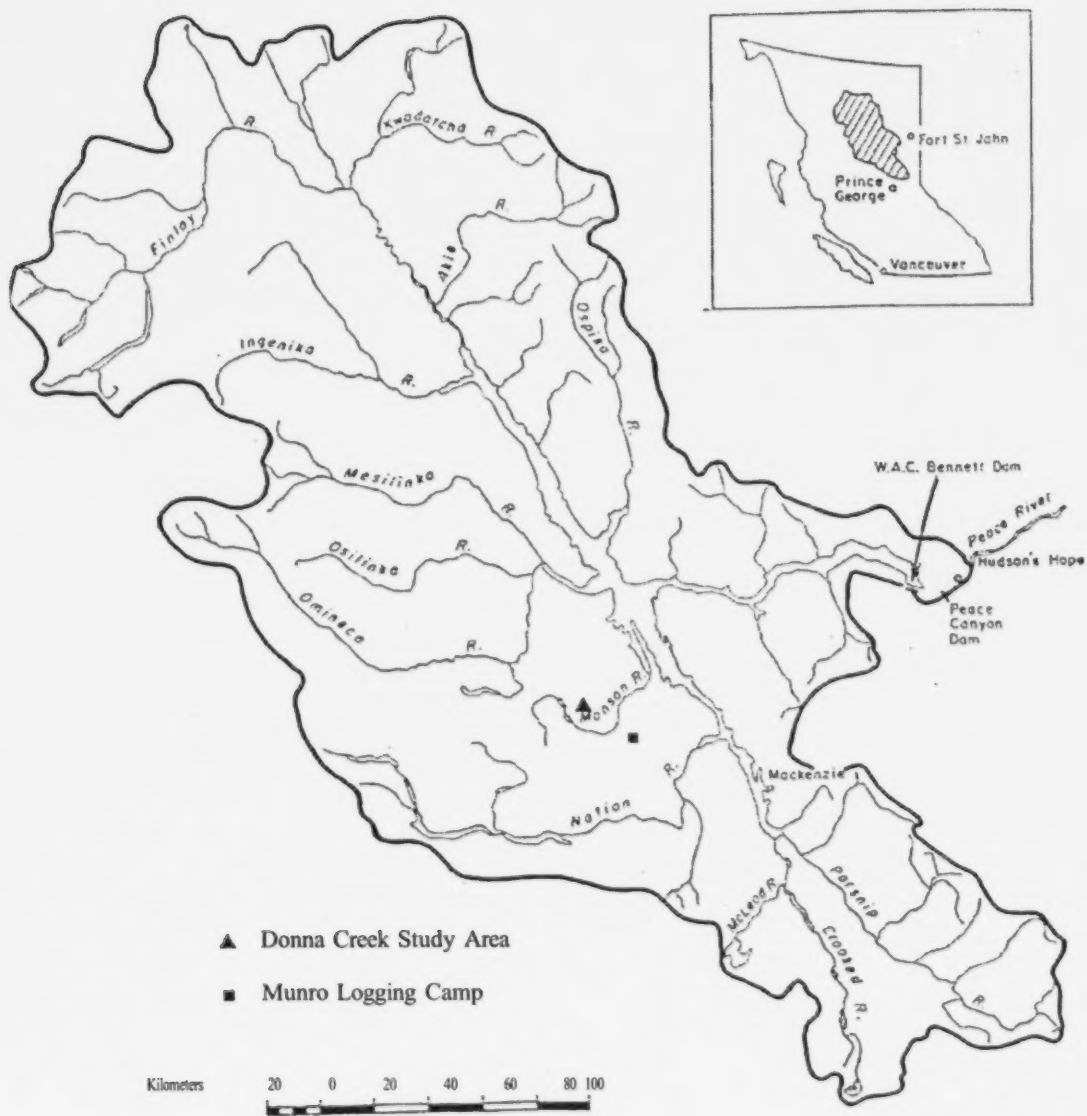


Figure 1. Location of the Donna Creek Study Area in British Columbia.

2.0 STUDY AREA

The Donna Creek study area is located at the south end of the Wolverine Range of the Omineca Mountains, approximately 80 kilometres northwest of Mackenzie and 240 km north of Prince George, British Columbia (Figure 1). Detailed location notes and geographical descriptions of the study area are available in Dawson et al. (1992). The study area is in the Manson Plateau Ecoregion of the Omineca Mountains Ecoregion of the Sub-Boreal Interior Ecoprovince. The study plots are in the moist very cold variant of the Engelmann Spruce Subalpine Fir Biogeoclimatic Zone (ESSFmv3). This zone is characterized by an ericaceous shrub layer, a sparse cover of herbs, and a relatively dense moss layer. Engelmann spruce and subalpine fir are the dominant climax tree species, with lodgepole pine as a widespread seral species (Dawson et al. 1992).

3.0 METHODS

3.1 STUDY DESIGN

3.1.1 Effects of Stubs and Tree Islands within Clearcuts

The study design was a randomized block two-factor ANOVA with two levels of each between-subjects factor (i.e., a 2x2 ANOVA) including one within-subjects factor since the data was collected over two years. The design permitted determination of the main effects of each between-subjects factor on breeding bird densities and richness, as well as the interaction effects of the factors, and the effect of variation between years (Table 1). The first factor was the retention of stumps (high stumps cut at 3-m height by the feller buncher) within the clearcut. Levels chosen were 1)absence and 2)densities of 8-10/ha. The second factor was the retention of mature tree islands, or patches of residual forest, within the clearcut. Levels chosen were 1)absence and 2)3-4 tree islands of $\pm 1/4$ ha each in size per 25 ha.

Table 1. 2x2 randomized-block ANOVA design used for analysis of breeding bird detection densities within experimental blocks.

Source of Variation	Degrees of Freedom
Between-Subjects Factors	
Stub Effect (S)	1
Tree Island Effect (I)	1
S*I Interaction Effect	1
Block Effect	2
Error	6
Within-Subjects Factors	
Year	1
Error	11
23 total d.f.	

There are four possible combinations of the two experimental factors at each of two given levels. These combinations make the following four treatments:

- Clearcut (CT): no stubs-no tree islands,
- Stub (SB): stubs but no tree islands,
- Tree-Island (TI): tree islands but no dispersed stubs¹,
- Stub-and-Island (SI): stubs and tree islands.

Each of the three experimental blocks (Blocks 5516, 5546 and 5547; see Fig. 2) was divided into four sections of about 25 ha each, and one of each treatment applied in each experimental block. This made for a randomized block study design with 3 replicates of each treatment. Each of the treatments is referred to hereafter by the two-letter code (CT, SB, TI, or SI) to avoid confusion between the stub and tree-island factors, and the treatments which are each a combination of different levels of the two factors.

An additional within-subject factor was time, i.e., the data was collected for two breeding seasons. This made for a Repeated Measures Design for the time factor. Where the Year effect was significant ($P \leq 0.05$), the two years had to be analyzed separately, but where the Year effect was not significant, the data from the two years is, in effect, averaged within the experimental design. Where the 1995 and 1996 results are not reported separately in the Tables, then the results are the combined averages of the 1995 and 1996 data because the two years of data were not significantly different.

3.1.2 Comparison of Clearcut Treatments to Clearcut Controls

To discount the possibility that "neighbour effects" of adjacent areas with stubs or tree islands were contributing to some bird use of the Clearcut Treatments (CT), large clearcuts with no stubs or tree islands were selected within the Donna Creek drainage to act as controls to the treatment clearcuts. These were termed Clearcut Controls (CC). Sampling was conducted in the Clearcut Controls (Blocks 5510, 5549 and 5550, see Fig. 2) at the same intensity as in the Clearcut Treatments to permit valid comparisons between the treatment and control clearcuts. Year effect was also analyzed as a within-subjects factor. Where the Year effect was significant ($P \leq 0.05$), the two years were analyzed separately for differences in Clearcut Treatments and

Table 2. Experimental Design used for Clearcut Treatment to Clearcut Control Contrasts.

Source of Variation	Degrees of Freedom
Between-Subjects Factors	
Clearcut Treatment to Clearcut Control contrast	1
Error	4
Within-Subjects Factors	
Year	1
Error	5
	11 total d.f.

¹A fringe of stubs was created at the immediate edge of each tree island during timber harvest. Therefore each tree island is also a high-density patch of stubs as well as a patch of residual forest.

Clearcut Controls and the results for 1995 and 1996 are presented separately. However, where the Year effect was not significant, only a single result is presented which represents the average from the two years.

3.1.3 Effectiveness of Stubs and Tree Islands as Mitigation for Old-Growth Species

Sampling was conducted in old-growth forest adjacent to each of the experimental cutblocks (5516, 5546 and 5547). These were termed Old-Growth Controls (OG). This permitted comparisons of mean breeding bird use in each of the four treatments with the mean use in the old-growth forest. The choice of Old-Growth Controls did not allow for the randomized block design since the Old-Growth Control for Block 5546 was in the corridor of forest between blocks 5546 and 5547. There was no good basis to assign this as a control for one block in preference to the other block. A completely randomized design one-factor ANOVA was therefore used for old-growth to treatment comparisons. Each treatment was considered a single factor in this experimental design. Year effect was also analyzed as a within-subjects factor. Where the Year effect was significant ($P \leq 0.05$), the two years were analyzed separately for differences in treatments to Old-Growth Controls and the results for 1995 and 1996 are reported separately. However, where the Year effect was not significant, only a single result is presented which represents the average from the two years.

Table 3. Experimental Design used for Old-Growth Control contrasts to Experimental Treatments.

Source of Variation	Degrees of Freedom
Between-Subjects Factors	
Experimental Treatments to Old-Growth Control contrast	4
Error	10
Within-Subjects Factors	
Year	1
Error	14
	29 total d.f.

3.2 DESCRIPTION OF EXPERIMENTAL TREATMENT STUDY SITES

Three experimental cutblocks were chosen for this study (Cutting Permit 371, Block 5516, and Cutting Permit 373, Blocks 5546 and 5547), located between 1000 and 1330 m, with the lower portions of blocks 5546 and 5547 located in the valley bottom of Soloman Creek, the main tributary to Donna Creek (Figure 2). Most of the area of the cutblocks is on moderate to strong undulating slopes (13%-24%) with a southwest exposure. The uneven topography results in a complex of soil moisture regimes including well drained slopes, wet seepage areas and ponded areas on plateaus. The characteristics of the experimental cutblocks have been previously described by Wood (1992). These descriptions are only very briefly summarized here. The exact placement of each tree island and treatment unit within each block is shown in Figure 3 with the area of each experimental unit and the total area retained as tree islands within each experimental unit summarized in Table 4.

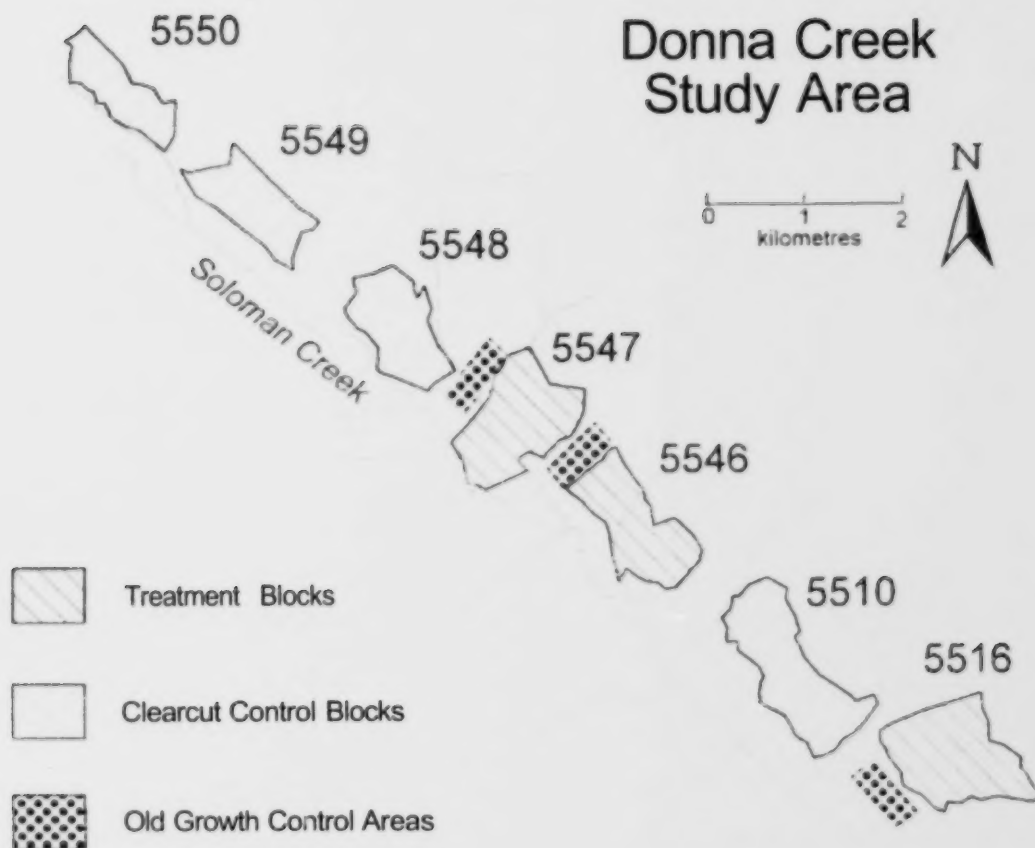


Figure 2. Location of the Experimental Treatment cutblocks, the Clearcut Control cutblocks, and the Old-Growth Control areas in the Donna Creek Study Area.

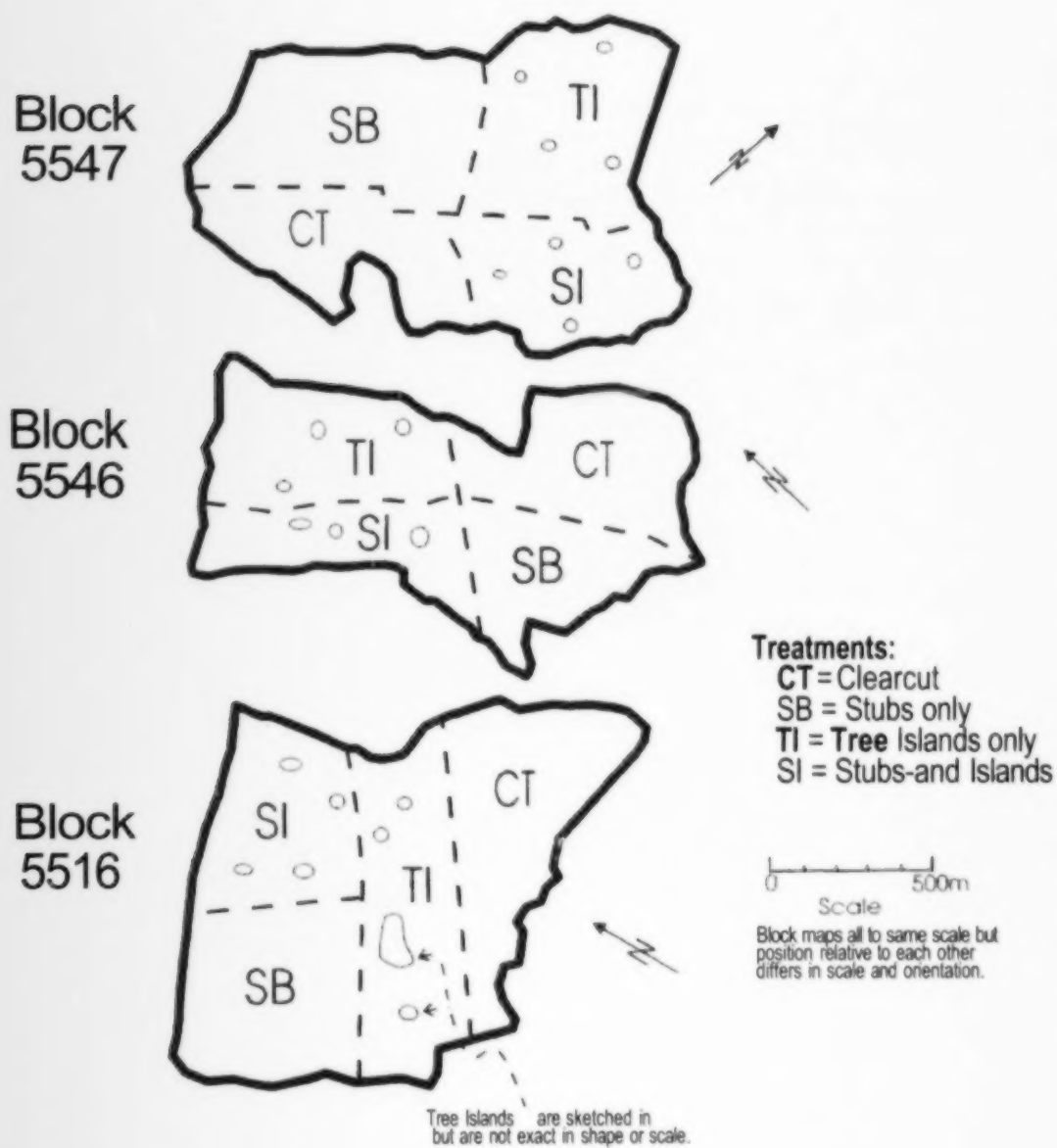


Figure 3. Location of experimental treatment units and tree islands within Blocks 5516, 5546 and 5547 in the Donna Creek Study Area.

Table 4. Total areas and tree-island areas of experimental Treatment Units.

Treatment Unit	Block 5516		Block 5546		Block 5547	
	Total Area ha	Island Area ha (%)	Total Area ha	Island Area ha (%)	Total Area ha	Island Area ha (%)
Clearcut (CT)	34.8	0	23.7	0	24.7	0
Stub (SB)	31.8	0	20.0	0	32.6	0
Tree-Islands (TI)	34.0	2.36 (6.9%)	25.2	0.81 (3.2%)	29.4	0.96 (3.3%)
Stubs-and-Islands (SI)	26.6	1.05 (3.9%)	23.6	0.83 (3.5%)	26.5	1.04 (3.9%)

•*Experimental Block 5516* The block is crossed by many very small runoff creeks and is the wettest of the three experimental cutblocks. Seven tree islands ranging between 0.26 and 0.40 ha in size (mean= 0.30 ha) were created in this block by reserving patches of trees from clearcutting. One additional tree island of 1.4 ha was reserved from clearcutting because of slope instability concerns. This largest tree island was also the only tree island that was not "ringed" with stubs created by high-cutting trees during timber harvesting. All other tree islands had high concentrations of stubs at their edges. Block 5516 was logged in August/September 1992.

•*Experimental Block 5546* Six tree islands ranging between 0.22 and 0.37 ha in size (mean= 0.31 ha) were created in this block. Block 5546 was logged in October 1991.

•*Experimental Block 5547* Eight tree islands ranging between 0.18 and 0.33 ha in size (mean= 0.25 ha) were created in this block by retaining trees during clearcutting. Block 5547 was logged in October 1991.

3.3 BREEDING BIRD SAMPLING METHODS

Point counts with a 50-m fixed radius were used to sample breeding birds as described by Hutto et al. (1986). We used 50-m as the radius because we had a reasonable expectation that all birds that would sing within this radius during a 10-minute count period would be heard and counted, i.e., we could likely discount most effects of threshold detection distances for most species. Seven points were established in each treatment unit (CT, SB) without tree islands and in each control area (CC, OG). Points in Old-Growth Control areas were placed at 175-m intervals along straight transect lines parallel to, and 150 m from, the adjacent clearcut block boundaries. Points in clearcut areas were established to give relatively even coverage of the treatment units spaced at 125-m intervals. The treatment units with tree islands (TI, SI) were stratified into 2 habitats for sampling: tree islands, and the clearcut matrix around the tree islands. In these treatments, sampling points were established first at the approximate centre of each tree island to give total coverage of the tree islands. The only exception was the largest 1.4-ha tree island in Block 5516 where 2

points were required, and because of the shape of the tree island only 90% of the island area was sampled using 50-m radius plots. The next 7 points were placed in the clearcut matrix to give relatively even coverage and still maintain a minimum distance between points of 115 m to prevent overlap in sampling area with any of the other points. The exact locations and survey marks of each point have been described in Joy and van den Driessche (1995).

All sampling was conducted between 0415 and 1000 hrs Pacific Daylight Time. A single survey round consisted of sampling all 149 points once and took 3-4 days to complete with 3 observers in 1995, and 4-6 days to complete in 1996 with 2 observers. Details of the sampling procedures can be found in the summary reports of Joy and van den Driessche (1995 and 1996). However, to summarize here, seven survey rounds of the points were made between May 22 and June 26, 1995, and between May 29 and July 4, 1996. A single point count sample at each point was conducted using only one person. Sampling at any given point was alternated between observers to attempt to minimize any effects from observer bias. During a 10-minute sampling period, all birds detected by sight or sound within 50-m of the point were recorded. The data recorded for each bird which was used for analyses in this report included the species and the activity (particularly singing or non-singing). For points within tree islands, the location of the bird inside or outside of the island was also recorded. Sampling within old-growth and tree islands began one minute after the observer had reached the sampling point to allow bird activity to adjust to the presence of the observer. Sampling at points within non-forested habitats began as soon as the observer reached the 50-m radius boundary so that any birds flushed on the approach would be included in the sampling period as suggested by Hutto et al. (1986).

In 1996, additional vegetation and physical data were collected at the bird sampling points. The methods of collection are on file at the Peace/Williston Fish and Wildlife Compensation Program office in Prince George. A portion of that data is summarized in the results of this report to better describe the bird sampling points and to determine if vegetation or physical characteristics of blocks and treatments differed. All data used in this report were collected within either an 11-m radius plot (0.038 ha) or 50-m radius plot (0.785 ha) centred on the bird sampling points. Data collected within the 11-m radius, and which are analyzed in this report, were the density of snags > 15 cm dbh, % area covered by different soil moisture regimes, and % area covered by: bare soil and rock, downed wood, moss, grass, fireweed (the most abundant herb on the clearcut sites), other herbs, total herbaceous and grass cover, deciduous low shrubs (woody shrubs up to 0.5-m height), coniferous low shrubs, total low shrubs, deciduous tall shrubs (woody shrubs between 0.5 and 2.0-m height), coniferous tall shrubs, total tall shrubs, sub-dominant tree cover (2 to 10-m height) by species, and dominant canopy trees by species. Data collected within the 50-m radius, and which are analyzed in this report, were the stub density within 50-m, and the % area covered by different soil moisture regimes.

3.4 DATA ANALYSIS

All analyses were done using NCSS software (Hintze 1992) except for Dunnett's Procedure which only used NCSS to provide ANOVA Mean Square Error for input to the procedure. Generalized Linear Model (GLM)-ANOVA was used throughout. ANOVA is relatively robust to heterogeneity of variances when the numbers of replicates are equal (Maxwell and Delaney 1990:703), so heterogeneity of variances was not tested. With only three replicates per treatment or control, it was not possible to test for normality of data distribution, although we have proceeded with ANOVA that assumes normal distributions. ANOVA is also robust to all but extreme violations of the normality assumption if sample sizes are equal (Maxwell and Delaney 1990:708). All tests made were two-tailed since individual species could respond positively or negatively to any of the factors or treatments. The probability of a Type I error (α) was set at 0.05 throughout the analyses.

3.4.1 Bird Detection Densities²

Bird detection counts from the points had to be adjusted for area because of the stratified sampling methods used, and because the tree island points sampled unequal areas of tree island depending on the tree island size. For these tree island points, only birds detected within the tree islands were included in the calculations of density for the analyses. The sampling points and the survey rounds within a single treatment unit were not considered independent samples. Only treatments in separate cutblocks were considered independent replicates of a given treatment. Therefore the sampling points and survey rounds were only sub-samples within a treatment replicate, and were not treated separately. All calculated mean densities are the mean for an entire treatment, consisting of the average of the 3 replicates (one in each cutblock). Throughout the report, the term "density" will be used, even though it is understood that this refers to "detection densities" rather than true densities in terms of numbers of territories or nests per unit area.

Densities of individual species were calculated by summing all detections of a species within a single treatment replicate, and then dividing by the total area sampled within the replicate. The total area sampled was the product of the number of points, number of survey rounds, and the area sampled at each point. For replicates without tree islands, the total area sampled was 38.48 ha (7 points x 7 rounds x 0.7854 ha/point). For tree island points within a treatment replicate, densities were calculated by summing the birds detected in tree islands, and dividing by the product of number of rounds and the total tree-island area sampled. For treatments with tree islands, where sampling was stratified by habitat, i.e., clearcut and tree island, total densities were estimated using the weighted sum of the 2 strata according to the relative proportion of total area occupied by each (see Table 4).

²The term "detection densities" has been used because these are relative densities based on the numbers of birds detected per unit area in 10-minute periods. These are not equivalent to the density of territories that would be calculated from spot-mapping.

The densities are expressed as birds detected per 100 ha (or 1 km²) simply for notational convenience. For instance, a density of 4.3 birds/100 ha is the equivalent of 0.043 birds/ha and could also validly be expressed that way. Between species comparisons are not entirely appropriate with this data because different bird species will have different detectabilities, especially territorial songbirds compared to more silent species. For species that were predominantly detected singing (i.e., most songbirds), analyses were completed using singing birds only to reduce bias in densities when young or females may be counted. For other species, analyses were completed using all detections made.

3.4.2 Between Treatment Comparisons-Stub and Tree-Island Effects

To determine if the Clearcut Treatment (CT) replicates were valid representatives of clearcuts in general, or whether there was some "neighbour effect" from tree islands and stubs adjacent to the treatments, bird densities were contrasted between the CT treatments and the Clearcut Controls (CC) with one-factor ANOVA for any species with > 20 total detections in the CT and CC areas. Only after this comparison showed that the CT treatments were representative of clearcuts in general, the 2x2 ANOVA model (see Sec. 3.1.1) was used to determine stub and tree-island factor effects and interaction effects of the 2 factors on individual bird species densities. Analyses are presented for all species with at least 20 detections within the treatments.

3.4.3 Treatment to Old-Growth Control Comparisons

Bird densities in the Old-Growth Controls (OG) were compared to densities in the treatments (CT, SB, TI, SI) using Dunnett's Procedure (Dunnett 1955) which compares treatment means individually to the control mean using the Mean Square Error from the one-way ANOVA (see Sec. 3.1.3). This test is more powerful than other multiple-means comparisons for a given level of significance because fewer total comparisons are made. This procedure uses a joint significance level which was set at $\alpha = 0.05$. Analyses are presented for all species with > 25 detections in total, or at least 10 detections in the Old-Growth Controls alone.

3.4.4 Tree Islands as Habitat Islands

This experiment used a subset of the data from the previous experiments so that no extra point counts needed to be done. Tree islands were treated as a separate habitat for this analysis to determine which species were found in the tree islands, i.e., were they species commonly found in Clearcut Controls (CC), Old-Growth Controls (OG), or was there a unique set of species that relied on tree islands as habitat.

Densities of common species in 3 "habitats" (OG, CC, and the tree islands alone without including the surrounding clearcut matrix) were compared through one-factor ANOVA with three replicates of each factor, to determine which "clearcut" species and

which "forest" species made significant use of tree islands. For these comparisons, all the bird detections within tree-island points within a single block were summed and divided by the total tree-island area sampled (product of 7 rounds and total tree island area). Using the sum of all the tree islands in a single block (i.e., in both the TI and SI treatments) made for approximately equivalent sample sizes in each of the OG, CC and "tree island" replicates to provide less bias when using ANOVA. Results are presented for all species with > 25 total detections, and for any species with at least 15 detections within a single "habitat" type. Where the one-factor ANOVA was significant ($P \leq 0.05$), up to 3 pairwise comparisons were made using Tukey's test to determine significant differences in densities between "habitats".

3.4.5 Bird Communities

Bird community macroparameters such as species richness and diversity were not emphasized in this report because not all the treatments and controls were not sampled with equal effort. In particular, the treatments with islands were sampled separately by habitat strata so that species counts might be expected to be unequal simply because of the sampling strategy.

However, differences in species richness (count of numbers of species detected) were examined making allowances for differences in sampling area through Analysis of Covariance (ANCOVA) when sampling areas were unequal. The following comparisons were made: Clearcut Controls (CC) were compared to Clearcut Treatments (CT); multiple comparisons were made between Old-Growth Controls (OG) and the four experimental treatments (CT, SB, TI, SI) but only using data collected in points outside of the actual tree islands; multiple comparisons were made between the Old-Growth Controls (OG) and the four experimental treatments (CT, SB, TI, SI) including the tree island data and adjusting for area as a covariate; and, the species richness of the tree islands were compared to the clearcut areas immediately surrounding the islands, also adjusting for sampled area as a covariate. When adjusting for area as a covariate, the Year effect had to be tested separately first since the statistical package did not allow for both a covariate and a within-subjects factor within the same analysis. However, no between year differences were found in any of the species richness analyses, so that the year effect appeared to be very minor. The species richness statistics used was "species encountered per replicate per year". Therefore means were calculated separately for each year, and the overall averages do not represent a cumulative total of different bird species encountered in the two years. Multiple comparisons were tested for significance using Scheffé's test.

To better describe the similarities of species composition between the treatments (CT, SB, TI, SI) and Old-Growth Controls (OG), Simple Averaging hierarchical clustering provided graphical comparisons using singing birds only. Euclidean distance was used to develop clustering dendrograms. Euclidean distance is sensitive to species composition and abundance as well as to dominant species (van Tongeren 1987).

3.4.6 Vegetation and Physical Characteristics

Two analyses were undertaken. First, vegetation and physical characteristics were examined for differences between treatments and between blocks using ANOVA. A single mean for the seven points was calculated for each treatment or control replicate, and this mean used within the ANOVA. This was to determine if factors other than those the experiment was designed to detect (i.e. stubs and tree islands within clearcuts) were different between blocks or treatments, and whether these might have affected results for some species.

Second, for all cavity-nesting species and for species richness, correlations were sought with vegetative and/or physical characteristics. Stepwise linear regression was used where the dependent variable was the density of each species at each sampling point, and the independent variable(s) were the vegetative or physical characteristics. This analysis was different from all the other analyses in this report in that each species density at each point were considered, rather than averages or sums over all points within a replicate of a treatment type or a control. No attempt was made to apply stepwise regression to all of the common species because of the high likelihood of spurious correlations when using a large number of bivariate correlations (Wiens 1989a:284). I also used this method to assist in clarifying the response to the experimental factors for some other common species, in particular those whose densities appeared to respond to the experimental factors but with such high variability that significant differences could not be shown. I also applied this method to a few of the common species that did not appear to respond to the experimental factors but for which strong affinities to vegetative characteristics were suspected.

4.0 RESULTS

Fifty-four species of singing (or territorially-advertising) birds were detected in total. Fourty of these were detected in 1995 with an additional 14 new species detected in 1996. However, nine of the species detected in 1995 were not detected again in 1996. Full results for singing birds are given in Appendix 1 while most of the analyses deal only with species common enough to be entered in the analyses. In total, 2378 detections of 41 singing bird species were made in the 12 experimental treatment replicates, 1143 detections of 37 singing bird species in the 3 Old-Growth Control replicates, and 653 detections of 17 singing bird species in the 3 Clearcut Control replicates.

Seventy species of birds were recorded in all sampling with 59 species detected in 1995 and an additional 11 new species detected in 1996. However, 13 of the species detected in 1995 were not again detected in 1996. Full results for all bird species are given in Appendix 2 while the rest of the analyses deal only with species common enough to be entered in the analysis. 5863 detections of 61 bird species were made in the 12 experimental treatment replicates, 1769 detections of 42 bird species in the 3 Old-Growth Control replicates, and 1294 detections of 26 bird species in the 3 Clearcut Control replicates.

Fourteen of the total of 70 bird species detected (20%) were cavity-nesting species which accounted for 5.9% of the total detections (523/8926). Nine of these 14 species were detected frequently enough to include in the analyses. The brown creeper, boreal chickadee and winter wren were largely confined to the Old-Growth Controls; the mountain bluebird, tree swallow, and American kestrel were largely confined to the treatment areas; and the red-breasted nuthatch, black-backed woodpecker and three-toed woodpecker were found in both the treatments and in the Old-Growth Controls.

Five of the 14 cavity-nesting species were detected too infrequently to be included in any of the analyses and will be dealt with briefly here. The boreal owl, northern hawk owl and northern pygmy owl were detected only once each within the sampling. The boreal owl was only recorded in 1995 when one was detected in a point count on June 14, and was present (although not detected again in point counts) until termination of field sampling on June 26 in the old-growth forest adjacent to Block 5516. The northern pygmy owl was only detected once on a point count on June 8, 1996, in the old-growth forest adjacent to Block 5546. The northern hawk owl was only detected once on a point count on May 29, 1996, in a tree island in Block 5546. Northern flickers were detected only 3 times, and only in tree islands within Block 5516 in 1996. Hairy woodpeckers were detected 16 times, 13 in 1995 and 3 in 1996. In 1995 they were detected in Old-Growth Controls and in the one tree island where they nested. In 1996 they did not appear to nest in any of the tree islands.

4.1 STUB AND TREE-ISLAND TREATMENT EFFECTS

No bird species exhibited significant differences in mean densities between the Clearcut Treatments (CT) and the Clearcut Controls (CC) (Table 5). The Clearcut Treatments therefore appeared to act like "real" clearcuts even though there were clearcuts immediately adjacent to them which contained stubs and/or tree islands. The rest of the 2x2 ANOVA designed to show stub and tree-island effects could then proceed using the Clearcut Treatments (CT) as valid representatives of clearcuts in general.

One likely difference which may have been masked by high within factor variability between the clearcut treatments and controls was for tree swallows. None were ever detected in the CT, but 25 in total (mean of 10.8/100 ha) were detected in the CC. However, this difference was not significant because the variance was so high in the Clearcut Controls with 18 of the 25 detections coming from only one replicate (see Appendix 2) so that the mean of 10.8 birds detected/100 ha is correctly interpreted as not being significantly different from zero.

No significant interaction effects between stubs and tree islands could be shown for any of the 16 species abundant enough for analysis, or for total densities of birds (Tables 6 and 7). Stubs had positive effects on densities of only yellow-rumped warblers. Tree islands had positive effects on the densities of Swainson's thrushes, yellow-rumped

Table 5. Bird Densities of the Clearcut Treatments (CT) compared to the Clearcut Controls (CC).

Species	Year	Mean Density of Detections (/100 ha)		ANOVA Statistics					
		Clearcut Control CC	Clearcut Treatment CT	Year Effect			Experimental Effect ¹		
				MSE ²	FW	P	MSE ²	FM	P
BIRO SPECIES ANALYZED USING ONLY SINGING DETECTIONS									
American robin	95&96	5.6	3.5	26.67	1.71	.25	39.94	0.35	.58
Chipping sparrow	95&96	16.9	14.7	168.0	0.08	.28	226.8	0.06	.82
Dark-eyed Junco	95&96	40.3	37.2	347.6	3.89	.11	164.3	0.17	.70
Lincoln's sparrow	1995	128.2	86.6	837.4	47.46	.00	468.1	5.54	.08
	1996	64.1	45.0				137.3	3.97	.12
MacGillivray's warbler	95&96	13.9	6.1	9.45	2.14	.20	99.02	1.84	.25
Savannah sparrow	95&96	52.8	35.5	853.0	1.28	.31	1610	0.56	.50
Wilson's warbler	95&96	26.4	7.4	85.97	1.68	.25	760.7	1.43	.30
Yellow-rumped warbler	95&96	7.8	3.9	37.47	0.14	.73	42.20	1.08	.36
All Singing Detections	1995	328	216	1297	16.32	.01	4339	4.38	.10
	1996	237	138				2892	5.06	.09
BIRD SPECIES ANALYZED USING ALL DETECTIONS									
Mountain bluebird	95&96	2.6	9.1	26.67	0.19	.68	177.2	0.71	.45
Pine siskin	95&96	37.2	50.2	1174	1.30	.31	539.6	0.94	.39
Tree swallow	95&96	10.8	0	34.77	0.15	.72	128.8	2.73	.17
All Birds	1995	624	503	4426	11.29	.02	7409	2.98	.16
	1996	496	373				13468	1.68	.28

¹ where Year Effect significant ($P \leq .05$), Habitat Effect tested separately for each year.² Mean Square Error term that was used in denominator to calculate F; F is followed by numerator and denominator d.f.

warblers and of the total of all birds detected. There was a significant block effect for golden-crowned sparrows, mountain bluebirds and yellow-rumped warblers in 1995 and 1996 and for pine siskins and Wilson's warblers only in 1995. Each of these species was most abundant in Block 5516. Annual variations in densities were only significant for American robins, Lincoln's sparrows, MacGillivray's warbler, Wilson's warbler, black-backed woodpeckers and for total densities of all singing birds and of all birds. MacGillivray's warblers and Wilson's warblers were detected significantly more frequently in 1996 than in 1995, while the others were detected significantly more frequently in 1995 than in 1996.

Table 6. Bird Densities for common species analyzed using singing detections, and 2x2 ANOVA test statistics for stub and tree-island effects using randomized-block design.

Species (N Detections)	Block	Density of Singing Detections (Number/100 ha sampled)				ANOVA Test Statistics [†]		
		Treatment ¹				Effect	F	P
		CT 95/96	SB 95/96	TI 95/96	SI 95/96			
American robin (93 Singing)	5516	7.8/5.2	26.0/5.2	4.7/1.8	6.1/7.1	Year	6.09	.03
	5546	0	5.2/2.6	0.6/4.2	11.8/3.1	Stubs (S)	0.57/0.01	.49/.92
						Tree Islands (I)	0.28/1.37	.61/.29
	5547	5.2/2.6	0	22.1/7.9	17.7/2.7	S*I Interaction	0.08/0.01	.79/.92
						Block	0.60/0.73	.58/.52
Chipping sparrow (238 Singing)	5516	20.8/5.2	18.2/13.0	27.9/11.0	16.1/16.2	Year	0.09	.78
	5546	10.4/31.2	15.6/28.6	10.4/11.2	18.1/26.9	Stubs (S)	2.86	.14
						Tree Islands (I)	0.28	.62
	5547	7.8/13.0	10.4/15.6	11.8/2.9	28.4/32.3	S*I Interaction	1.24	.31
						Block	0.38	.70
Dark-eyed junco (357 Singing)	5516	80.6/15.6	33.8/59.8	34.6/33.1	37.6/30.7	Year	0.32	.58
	5546	31.2/20.8	23.4/28.6	37.5/41.4	36.3/31.3	Stubs (S)	0.54	.49
						Tree Islands (I)	0.77	.41
	5547	36.4/39.0	18.2/33.8	30.1/16.9	19.1/24.1	S*I Interaction	0.04	.84
						Block	3.03	.12
Golden-crowned sparrow (34 singing)	5516	2.6/2.6	28.6/13.0	4.8/10.6	10.0/8.0	Year	0.48	.50
	5546	0	0	0	0	Stubs (S)	1.61	.25
						Tree Islands (I)	0.19	.70
	5547	0	0	0	0	S*I Interaction	1.21	.31
						Block	6.80	.03
Lincoln's sparrow (634 Singing)	5516	80.6/54.6	54.6/54.6	53.2/26.6	71.5/54.9	Year	21.80	.00
	5546	93.5/41.6	62.4/59.8	84.1/43.3	108.4/55.2	Stubs (S)	1.14/0.22	.33/.65
						Tree Islands (I)	0.61/0.00	.47/.98
	5547	85.7/39.0	85.7/33.8	167.4/66.3	64.0/39.5	S*I Interaction	0.00/0.00	.98/.39
						Block	1.28/0.13	.34/.88
MacGillivray's warbler (71 singing)	5516	10.4/7.8	0	1.8/2.4	0.0/0.5	Year	5.05	.05
	5546	0	0.0/7.8	9.2/12.6	3.1/3.7	Stubs (S)	1.89/0.27	.22/.62
						Tree Islands (I)	1.05/0.33	.35/.59
	5547	0.0/2.6	0.0/15.6	6.9/9.0	4.7/17.7	S*I Interaction	0.00/0.50	.35/.50
						Block	0.00/1.97	.99/.22
Ruby-crowned kinglet (25 singing)	5516	0	0	4.5/5.4	1.6/0.0	Year	0.14	.72
	5546	0	0	0	0	Stubs (S)	0.76	.42
						Tree Islands (I)	1.47	.27
	5547	0	0	0	0	S*I Interaction	0.76	.42
						Block	1.47	.30
Savannah sparrow (225 Singing)	5516	20.8/28.6	10.4/13.0	2.4/7.3	17.5/22.5	Year	0.72	.41
	5546	103.9/31.2	65.0/52.0	7.5/12.6	15.0/7.5	Stubs (S)	0.12	.74
						Tree Islands (I)	1.86	.22
	5547	2.6/26.0	18.2/13.0	45.2/25.1	15.0/15.0	S*I Interaction	0.06	.82
						Block	1.24	.35
Swainson's thrush (24 singing)	5516	0	0	2.3/3.2	1.1/1.1	Year	0.00	.98
	5546	0	0	0.0/0.6	0.6/0.6	Stubs (S)	0.20	.67
						Tree Islands (I)	7.11	.04
	5547	0	0	1.0/0.0	1.1/0.5	S*I Interaction	0.20	.67
						Block	1.47	.30

(Table 6 continued on next page)

Table 6. (Continued)

Species (N Detections)	Block	Density of Singing Detections (Number/100 ha sampled)				ANOVA Test Statistics ²		
		Treatment ¹				Effect	F	P
		CT 95/96	SB 95/96	TI 95/96	SI 95/96			
Wilson's warbler (298 Singing)	5516	13.0/13.0	26.0/23.4	27.0/33.0	9.5/25.5	Year	7.88	.02
	5546	0.0/5.2	0	7.0/39.5	3.0/14.1	Stubs (S)	0.42/0.60	.54/.47
	5547	2.6/10.4	23.4/18.2	9.8/26.8	11.9/26.5	Tree Islands (I)	0.02/13.31	.89/.01
Yellow-rumped warbler (190 Singing)	5516	10.4/2.6	13.0/10.4	13.5/11.4	13.6/17.5	S*I Interaction	5.87/3.13	.052/.13
	5546	0.0/2.6	5.2/13.0	2.3/5.7	11.1/9.2	Block	6.68/1.47	.03/.30
	5547	2.6/5.2	13.0/2.6	5.4/6.9	12.6/3.8	Year	0.35	.56
All Singing Detections (2378)	5516	257/138	244/192	192/168	207/192	Stubs (S)	24.43	.00
	5546	244/140	179/192	159/176	215/163	Tree Islands (I)	8.10	.03
	5547	146/138	177/140	302/167	181/168	S*I Interaction	0.97	.36
						Block	13.51	.01
						Year	9.18	.01
						Stubs (S)	0.23/4.72	.65/.07
						Tree Islands (I)	0.00/2.82	.97/.14
						S*I Interaction	0.00/3.14	.99/.13
						Block	0.24/1.58	.79/.28

¹CT = Clearcut Treatment, SB = Stubs Treatment, TI=Tree Islands Treatment, SI=Stubs and Tree Islands Treatment

² 1 numerator and 11 denominator degrees of freedom in RMD F-test for Year Effect;

1 num. and 6 denom. d.f. in every other F test except for Block which has 2 num d.f.;

where the Year Effect was significant ($P \leq 0.05$), other Effect statistics were presented separately for 1995 and 1996 (separated by a slash for 1995 and 1996 respectively).

Table 7. Bird Densities for common species that were analyzed using all detections, and 2x2 ANOVA test statistics for stub and tree-island effects using randomized-block design.

Species (N Detections)	Block	Density of All Detections (Number/100 ha sampled)				ANOVA Test Statistics ²		
		Treatment ¹				Effect	F	P
		CT 95/96	SB 95/96	TI 95/96	SI 95/96			
Black backed woodpecker (83)	5516	2.6/0.0	15.6/15.6	12.5/3.6	6.1/6.1	Year	8.60	.01
	5546	0	5.2/0.0	4.2/0.0	8.7/0.6	Stubs (S)	2.47/2.22	.17/.19
						Tree Islands (I)	1.90/0.04	.22/.85
	5547	0	0	2.5/2.5	11.5/5.7	S*I Interaction	0.48/0.40	.22/.55
Mountain bluebird (104)	5516	31.2/15.6	31.2/5.2	9.5/11.0	47.1/37.6	Block	1.71/2.21	.26/.19
	5546	0	26.0/2.6	0	0.6/2.5	Year	3.64	.08
						Stubs (S)	1.46	.27
	5547	2.6/5.2	0	0	0	Tree Islands (I)	0.03	.87
Pine siskin (527)	5516	83.2/26.0	119.5/46.8	84.8/30.5	103.4/24.8	S*I Interaction	0.78	.41
	5546	36.4/103.9	72.8/36.4	38.0/5.6	63.1/8.1	Block	6.00	.03
						Year	11.47	.01
	5547	49.4/2.5	28.6/10.4	35.1/10.1	43.3/10.5	Stubs (S)	4.53/0.18	.08/.69
Red-breasted Nuthatch (30)	5516	0	0	6.3/0.5	4.8/0.5	Tree Islands (I)	0.20/1.92	.67/.21
	5546	0	0	0	0.0/0.6	S*I Interaction	0.00/0.14	.99/.72
						Block	19.04/1.25	.00/.35
	5547	0.0/2.6	0	0.0/0.5	0.0/1.1	Year	0.45	.52
Tree swallow (51)	5516	0	13.0/0.0	4.8/5.7	10.0/5.0	Stubs (S)	0.13	.73
	5546	0	20.8/7.8	1.1/0.0	10.0/7.5	Tree Islands (I)	2.34	.18
						S*I Interaction	0.10	.76
	5547	0	5.2/2.6	3.0/16.5	0	Block	0.91	.25
All Birds Detected (5863)	5516	605/377	738/483	575/475	638/508	Year	0.92	.35
	5546	483/429	543/468	455/429	491/476	Stubs (S)	2.41	.17
						Tree Islands (I)	0.19	.67
	5547	421/314	408/338	631/462	495/415	S*I Interaction	2.17	.19
						Block	0.28	.76
						Year	25.54	.00
						Stubs (S)	0.23/1.95	.65/.21
						Tree Islands (I)	0.08/6.09	.78/.05
						S*I Interaction	0.53/0.90	.49/.38
						Block	3.98/4.21	.08/.07

¹CT = Clearcut Treatment, SB = Stubs Treatment, TI = Tree Islands Treatment, SI = Stubs and Tree Islands Treatment²1 numerator and 11 denominator degrees of freedom in RMD F-test for Year Effect;

1 num. and 6 denom. d.f. in every other F test except for Block which has 2 num d.f.;

where the Year Effect was significant ($P \leq 0.05$), other Effect statistics were presented separately for 1995 and 1996 (separated by a slash for 1995 and 1996 respectively).

4.2 TREATMENT TO OLD-GROWTH CONTROL COMPARISONS

Total bird densities, both for singing detections and for all detections, were significantly lower in all of the treatments than in the Old-Growth Controls using Dunnett's test (Table 8). Thirty bird species were detected frequently enough to analyze for differences in means between the Old-Growth Controls and the treatments. Fourteen species were significantly more abundant in the Old-Growth than in all treatments: blackpoll warbler, golden-crowned kinglet, northern Waterthrush, ruby-crowned kinglet, Swainson's thrush, Townsend's warbler, winter wren, yellow-rumped warbler, boreal chickadee, brown creeper, gray jay, red-breasted nuthatch, spruce grouse, and three-toed woodpecker. Some of these species did make significant use of tree islands (see section 4.3) but the overall effect of tree islands on densities within clearcuts appeared to be very minor because the tree islands made up such a small percentage of the treatment areas. Wilson's warbler was significantly less abundant only in Clearcut Treatments (CT) than in Old-Growth Controls. Only Lincoln's sparrows were significantly more abundant in most of the treatments than in the Old-Growth Controls. Chipping sparrows were more abundant in the Stubs-and-Islands Treatment (SI) than in Old-Growth Controls.

4.3 TREE ISLANDS AS HABITAT ISLANDS

Twenty-eight species of birds were detected frequently enough to analyze their densities in tree islands relative to the Clearcut Controls (CC) and Old-Growth Controls (Table 9). Only two species (Lincoln's sparrow and savannah sparrow) were detected significantly more frequently in Clearcut Controls than in tree islands or in Old-Growth Controls. Five species (blackpoll warbler, golden-crowned kinglet, Townsend's warbler, boreal chickadee and brown creeper) were detected significantly more frequently in Old-Growth Controls than in either tree islands or in Clearcut Controls. Five species (American robin, chipping sparrow, Wilson's warbler, yellow-rumped warbler and black-backed woodpecker) were detected significantly more frequently in tree islands than in Old-Growth or Clearcut Controls. Four species (Swainson's thrush, winter wren, evening grosbeak and gray jay) were significantly less abundant in Clearcut Controls than in Old-Growth Controls with densities in tree islands intermediate between the two extremes, and not significantly different from either. Densities of all birds and of singing birds were significantly higher in tree islands than in Clearcut or Old-Growth Controls.

No statistically significant differences in density could be shown for eight relatively common species (ruby-crowned kinglet, varied thrush, western wood-pewee, mountain bluebird, red-breasted nuthatch, spruce grouse, tree swallow and three-toed woodpecker) that were absent, or nearly so, from one or more of the three habitats. This was probably because of high variability in the results. In particular, each of the species were much more abundant in one or more of the replicates than in others of the replicates within the same habitat type (see Appendices 1 and 2). The correct interpretation of these non-significant

Table 8. Significance of Old-Growth Control to treatment comparisons of mean bird detection densities using Dunnett's test.

	Test of Year Effect		Year	Difference in Mean Density relative to Old-Growth ¹				Test Statistics ²	
	F _{1,18}	P		Clearcut CT	Stubs SB	Tree Islands	Stubs & Islands	MSE	Critical Difference
						TI	SI		
BIRD SPECIES ANALYZED USING ONLY SINGING DETECTIONS									
American robin	7.42	.02	1995	o	o	o	o	90.38	22.4
			1996	o	o	o	o	7.16	6.3
Blackpoll warbler	0.00	.99	95&96	-	-	-	-	17.59	9.9
Chipping sparrow	0.22	.65	95&96	o	o	o	+	28.28	12.6
Dark-eyed junco	1.18	.30	95&96	o	o	o	o	91.47	22.6
Golden-crowned kinglet	0.16	.70	95&96	-	-	-	-	40.73	15.1
Golden-crowned sparrow	0.48	.50	95&96	o	o	o	o	38.62	14.7
Hammond's flycatcher	1.47	.25	95&96	o	o	o	o	7.64	6.5
Lincoln's sparrow	15.90	.00	1995	+	o	+	+	871.42	89.7
			1996	+	+	+	+	149.52	28.9
MacGillivray's warbler	0.92	.35	95&96	o	o	o	o	20.32	10.6
Northern waterthrush	0.81	.38	95&96	-	-	-	-	3.15	4.2
Ruby-crowned kinglet	2.52	.13	95&96	-	-	-	-	7.20	6.3
Savannah sparrow	0.72	.41	95&96	o	o	o	o	350.64	44.2
Swainson's thrush	3.12	.10	95&96	-	-	-	-	22.43	11.2
Townsend's warbler	2.65	.13	95&96	-	-	-	-	108.84	24.6
Varied thrush	2.43	.14	95&96	o	o	o	o	30.74	13.1
Wilson's warbler	0.66	.43	95&96	-	o	o	o	56.33	17.7
Winter wren	0.91	.36	95&96	-	-	-	-	27.84	12.5
Yellow-rumped warbler	2.00	.18	95&96	-	-	-	-	55.31	17.6
All Singing Birds	13.15	.00	1995	-	-	-	-	3094.8	131.3
			1996	-	-	-	-	331.31	43.0
BIRD SPECIES ANALYZED USING ALL DETECTIONS									
Black backed woodpecker	1.86	.19	95&96	o	o	o	o	17.52	9.9
Boreal chickadee	0.13	.72	95&96	-	-	-	-	4.39	4.9
Brown creeper	1.91	.19	95&96	-	-	-	-	3.15	4.2
Evening grosbeak	5.73	.03	1995	o	o	o	o	34.90	13.9
			1996	-	-	-	-	2.29	3.6
Gray jay	1.05	.32	95&96	-	-	-	-	1.63	3.0
Mountain bluebird	3.48	.08	95&96	o	o	o	o	172.10	30.9
Pine grosbeak	5.62	.03	1995	o	o	o	o	11.66	8.1
			1996	o	o	o	o	3.58	4.5
Pine siskin	19.79	.00	1995	o	o	o	o	1066.37	77.1
			1996	o	o	o	o	685.27	61.8
Red-breasted nuthatch	3.62	.08	95&96	-	-	-	-	3.98	4.7
Spruce grouse	0.30	.59	95&96	-	-	-	-	7.24	6.4
Tree swallow	1.40	.26	95&96	o	o	o	o	14.69	9.0
Three-toed woodpecker	2.12	.17	95&96	-	-	-	-	5.68	5.6
All Birds	33.94	.00	1995	-	-	-	-	1093.4	248.5
			1996	-	-	-	-	2583.9	118.8

¹ Differences presented separately for 1995 and 1996 where Year Effect significant ($P \leq 0.05$);

- indicates mean density is significantly lower than Old-Growth Control,

o indicates mean density not significantly different from Old-Growth Control,

+ indicates mean density is significantly greater than Old-Growth Control.

² MSE is Mean Square Error of one-way ANOVA with 5 levels each with 3 replicates (10 d.f.);Critical Difference in density = $d \times (2MSE/n)^{0.5}$, where Dunnett's $d_{.05(4,10)} = 2.89$ and $n = 3$.

Table 9. Comparison of densities of common breeding bird species in Clearcut Control, Old-Growth Control and Tree Island habitats.

Species	Year	Mean Density of Detections ¹ (/100 ha)			ANOVA Statistics					
		Clearcut Control CC	Tree Islands	Old-Growth Control OG	Year Effect			Habitat Effect ²		
					MSE ³	F _{1,2}	P	MSE ³	F _{2,2}	P
BIRD SPECIES ANALYZED USING ONLY SWING DETECTIONS										
American robin	95&96	5.6 ^a	46.4 ^b	7.4 ^a	45.79	0.19	.67	352.5	9.05	.02
Blackpoll warbler	95&96	0.0 ^a	0.0 ^a	53.3 ^b	98.11	0.39	.55	69.05	75.73	.00
Chipping sparrow	95&96	16.9 ^a	102.4 ^b	6.1 ^a	830.0	4.30	.07	1140	14.65	.00
Dark-eyed junco	95&96	40.3 ^{ab}	58.1 ^a	26.9 ^b	201.6	1.42	.27	208.3	7.08	.03
Golden-crowned kinglet	95&96	0.0 ^a	0.0 ^a	52.4 ^b	39.86	0.24	.64	135.4	40.56	.00
Lincoln's sparrow	1995	128.2 ^a	27.4 ^b	0.0 ^b	461.3	6.77	.03	371.6	36.79	.00
	1996	64.1 ^a	12.4 ^b	0.0 ^b				139.8	24.80	.00
MacGillivray's warbler	1995	13.9	48.4	6.1	59.80	9.31	.02	564.8	2.70	.15
	1996	8.7	26.3	0				272.7	1.98	.22
Ruby-crowned kinglet	95&96	0.0	18.3	23.8	60.20	3.21	.11	689.3	1.35	.33
Savannah sparrow	95&96	52.8 ^a	0.0 ^b	0.0 ^b	263.7	1.12	.11	541.7	10.31	.01
Swinson's thrush	95&96	0.0 ^a	22.0 ^{ab}	31.6 ^b	112.8	2.70	.14	163.6	9.64	.01
Townsend's warbler	95&96	0.0 ^a	9.9 ^a	110.9 ^b	359.1	1.37	.28	373.3	60.52	.00
Varied thrush	95&96	0.0	2.2	9.1	18.88	3.94	.08	112.1	1.21	.36
Warbling vireo	95&96	4.8	7.0	2.6	30.20	0.00	.97	67.77	0.44	.67
Wilson's warbler	95&96	26.4 ^a	207.0 ^b	29.4 ^a	118.4	1.97	.20	4253	15.08	.00
Winter wren	95&96	0.0 ^a	4.4 ^{ab}	21.2 ^b	68.27	2.00	.20	130.6	5.77	.04
Western wood-pewee	95&96	0.0	13.1	1.3	33.62	0.85	.38	142.3	2.20	.19
Yellow-rumped warbler	95&96	7.8 ^a	140.7 ^b	56.7 ^a	611.2	0.51	.50	816.4	33.19	.00
All Singing Detections	1995	328 ^a	797 ^b	593 ^{ab}	68.97	7.25	.03	26977	6.13	.04
	1996	237 ^a	768 ^b	397 ^a				9674	22.75	.00
BIRD SPECIES ANALYZED USING ALL DETECTIONS										
Black-backed woodpecker	95&96	0.0 ^a	51.4 ^b	3.5 ^a	215.9	2.94	.12	320.4	15.45	.00
Boreal chickadee	95&96	0.0 ^a	0.0 ^a	7.8 ^b	12.47	0.12	.74	14.63	8.31	.02
Brown creeper	95&96	0.0 ^a	0.0 ^a	8.9 ^b	6.75	2.00	.20	10.50	9.14	.02
Evening grosbeak	95&96	0.4 ^a	2.9 ^{ab}	8.7 ^b	31.92	0.03	.86	19.86	5.39	.05
Gray jay	95&96	0.0 ^a	18.4 ^{ab}	33.8 ^b	339.3	2.83	.13	151.1	8.98	.02
Mountain bluebird	95&96	2.6	13.9	0.0	7.20	0.48	.51	291.8	1.12	.38
Pine siskin	1995	53.7 ^a	199.8 ^b	89.2 ^{ab}	1996	18.34	.00	3165	5.50	.04
	1996	20.8	41.9	9.5				915.3	0.88	.46
Red-breasted nuthatch	95&96	0.0	23.3	23.0	533.5	1.18	.31	515.6	2.08	.21
Spruce grouse	95&96	0.0	3.8	8.2	18.57	0.18	.68	31.54	3.23	.11
Tree swallow	95&96	10.8	9.1	0.9	59.39	0.05	.83	102.7	1.66	.27
Three-toed woodpecker	95&96	0.0	16.3	7.8	25.55	4.82	.06	210.0	1.90	.23
All Birds	1995	624 ^a	1780 ^b	895 ^a	12264	16.23	.00	57104	19.22	.00
	1996	496 ^a	1535 ^b	637 ^a				36210	26.32	.00

¹ where Habitat Effect significant ($P \leq .05$) means followed by like superscripts are not significantly different using Tukey's test.² where Year Effect significant ($P \leq .05$), Habitat Effect tested separately for each year.³ Mean Square Error term used in denominator to calculate F.

findings in these cases is that the variance was high enough that the means were not significantly different from zero.

Of the final 4 of the 30 common species not previously mentioned (dark-eyed Junco, MacGillivray's warbler, warbling vireo and pine siskin) for which no significant habitat effect could be shown or surmised, only the dark-eyed Junco appeared to be a true habitat generalist that was found at relatively equal densities in all habitats. Pine siskins tend to flock even during the breeding period and used a variety of habitats. Densities of MacGillivray's warblers and warbling vireos were found to be better correlated with vegetative factors that are dealt with later in this report (see Sec. 4.5.3).

4.4 BIRD COMMUNITIES

The Clearcut Controls (CC) did not contain significantly more or less species than the Clearcut Treatments (CT) (Table 10, Analysis 1) so that the Clearcut Treatments appeared to be valid representatives of clearcuts in general. There were also no significant annual effects in species richness.

On average, the presence of stubs in a clearcut increased species richness by 2.2 species over a clearcut without stubs (16% increase) although this was not statistically significant, nor was this result consistent in all cases. The presence of tree islands increased species richness significantly by 8.9 species over a clearcut without tree islands (66% increase). This species-enrichment effect of tree islands was noted in every case. However, even with these mitigative measures, the average species richness of clearcuts with tree islands was still 4.5 species lower than in Old-Growth Control forests, despite the extra sampling points in the treatments containing tree islands.

When the island point counts were not included in the species totals, no significant differences could be shown between any of the four experimental treatments (CT, SB, TI, SI) and the Old-Growth Controls (OG) had more species than any of the treatments (Table 10, Analysis 2). When the tree island points were included in the species counts per treatment, the Old-Growth Controls still had significantly more species than any of the treatments, but the treatments with tree islands and stubs (SI) had significantly more species than the Clearcut (CT) treatment, with the Stubs (SB) and Tree-Island (TI) treatments being intermediate and not significantly different from either (Table 10, Analysis 3).

The "block" factor was significant when looking at species richness. Block 5516 had consistently higher species richness than the other two experimental blocks in each of the experimental treatments and in the Old-Growth Controls (Table 10). Each treatment replicate in Block 5516 had 5-8 more species than the equivalent treatment in the other blocks in 1995, although this effect was not as pronounced or was absent in 1996. The possible causes of this effect were examined further in Sec. 4.5.

Table 10. Species richness of the experimental treatments, and Old-Growth and Clearcut Controls, and ANOVA test statistics.

Species Richness (Number Species Detected)												
Treatments										Controls		
		Clearcut		Stubs		Tree Islands (TI)			Stubs and Islands (SI)			Old-Growth
		CT		SB		Outside Islands	In Tree Islands	Total Area	Outside Islands	In Tree Islands	Total Area	OG
												CC
Block	Year	95	96	95	96	95	96	95	96	95	96	Block
5516		17	15	28	13	17	20	20	22	28	30	5510
5546		11	12	15	14	12	13	14	10	17	16	5549
5547		13	13	12	14	15	14	18	18	21	22	5550
Mean		13.5		15.7		15.2		17.0		22.3		13.8
Col.		A		B		C	D	E	F	G	H	I
												J

ANOVA TEST STATISTICS				
COMPARISONS MADE (Columns Used)	Effect Tested	d.f.	F	P
		num., denom.		
Clearcut Treatment (CT) to Control (CC) (A and J)	Year Effect	1,5	1.25	0.31
	Control to Treatment effect	1,4	0.01	0.91
OG and Treatments outside Islands (A, B, C, F, I)	Year Effect	1,14	4.37	0.06
	Treatment/Old-Growth factor ¹	4,8	56.14	0.00
	OG ^a > CC ^a , SB ^a , TI ^a , SI ^a			
	Block factor	2,8	17.01	0.01
OG and Treatments including Islands (A, B, E, H, I)	Year Effect (tested first separately in a within-subjects design)	1,14	2.11	0.17
	Sampled Area (as covariate)	1,7	5.88	0.05
	Treatment/Old-Growth factor ¹	4,7	26.83	0.00
	OG ^a > SI ^a ≥ TI ^a , SB ^a ≥ CC ^a			
	Block factor	2,7	7.50	0.01

means followed by like superscripts not significantly different;

CC = Clearcut Treatment, SB = Stubs Treatment, TI = Tree Islands Treatment, SI = Stubs and Tree Islands Treatment

Cluster analysis using all birds detected indicated that the bird communities of the Old-Growth Controls were very dissimilar to the treatment units. Two very distinct clusters formed within the dendrogram (Figure 4). The Old-Growth controls were more similar to each other than to any of the treatment units. Clustering patterns for the other treatment units were sometimes along block rather than treatment lines, but most often there was no apparent pattern to how the experimental treatments clustered.

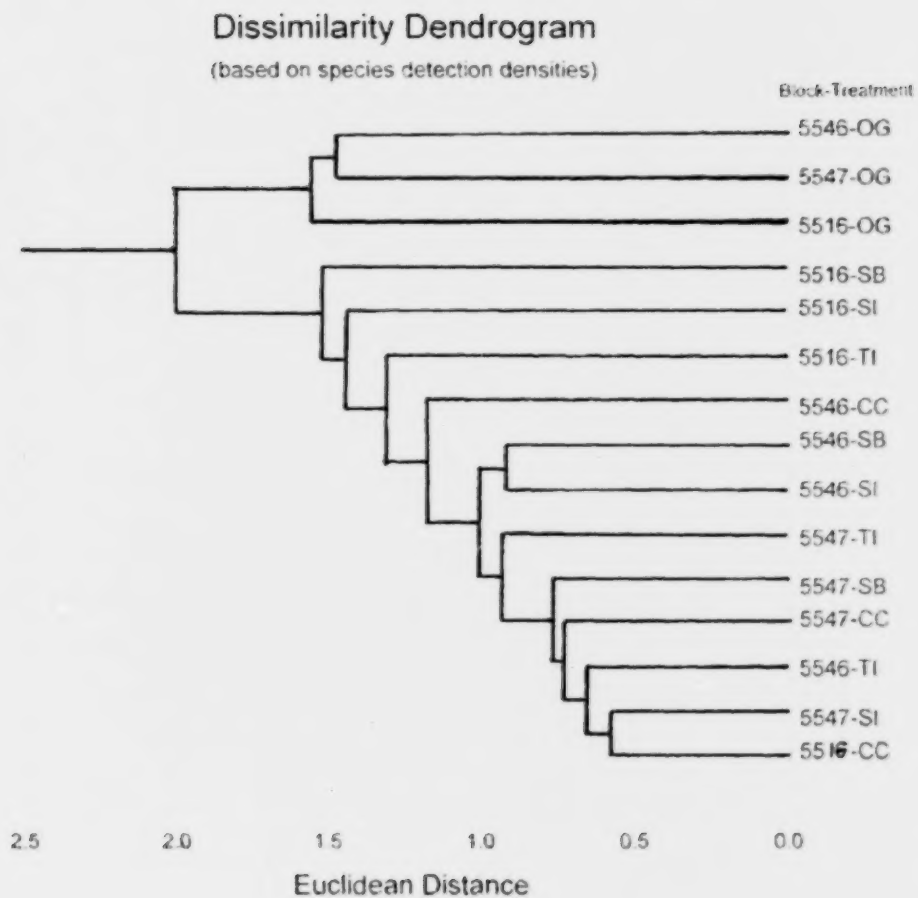


Figure 4. Simple Average cluster analysis dendrogram using Euclidean Distance on bird species detection densities.

4.5 VEGETATION AND PHYSICAL CHARACTERISTICS

4.5.1 Treatment and Block Differences

Vegetation and physical characteristics were examined for differences between treatments (Table 11). Tree cover was absent within the clearcut portions of the treatments and Clearcut Control, so differences in tree cover were examined only within tree islands and Old-Growth Controls. While no significant differences were found in individual tree species coverage, overall tree cover was lower in the tree islands than in the Old-Growth Control. This may have been because of blowdown in some of the tree islands that lowered the overall tree cover. Snag density did not significantly differ between the tree islands and Old-Growth Control.

Mean overall stub density was 9.0/ha in the clearcut areas of the SB and SI treatments (i.e. within 50 m of the bird sampling points, Table 11). Stub densities at these points ranged from 0-15.3/ha, with one point lacking any stubs because it was placed near a road intersection. Overall, 88% of the points had stub densities between 3.8 and 14.0/ha, and 62% of the points had stub densities between 5.1 and 12.7/ha. There were no significant differences in stub densities between any of the SB and SI treatments in any of the blocks (considering only those points outside of tree islands: $F_{5,41}=0.83$, $P=0.53$).

Stub densities at the edge of the tree islands (142/ha) were significantly higher than in the general clearcut areas of the SI treatments by design. Series of stubs were created during timber harvesting at the immediate perimeter of the tree islands. Stub densities in the tree islands were averaged over the whole area of the tree islands, even though the stubs occurred almost exclusively at the perimeter of the tree islands. If one were to calculate the actual density of stubs within the first few meters of the perimeter of the tree islands, the density would have appeared much higher than even 142/ha.

Tall shrub % cover was significantly lower in the clearcut areas than in the tree islands and Old-Growth Controls (Table 11). This was within the designed effect of the experiment since clearcutting also knocks down most of the tall shrub cover within the harvested area. There were no significant differences in low shrub % cover between treatments. Fireweed (*Epilobium angustifolium*) was the only very abundant herbaceous species in the clearcut areas and the only one analyzed separately here. It was absent in the tree islands and old-growth but very abundant in the clearcut areas (13-25% cover) although not significantly different between different treatments. Moss coverage was significantly higher in the tree islands and Old-Growth Control compared to the clearcut portions of the treatment areas. Overall moisture regimes did not differ between treatments.

Differences in vegetative and physical characteristics between blocks were examined only within the clearcut portions of treatments, within the tree islands, and within the Old-Growth Controls because of some basic differences in vegetation dictated by the experimental

Table 11. Mean vegetation and physical characteristics collected at bird sampling points and compared between treatments using ANOVA.

	Experimental Treatments ^{1,2}								Anova Test Statistics		
	Control ^{1,2}	"Clearcut" Portions				Tree-Islands		Control ^{1,2}	MSE	F	P
	CC	CT	SB	TI	SI	Ti	Si	OG			
Canopy Trees % Cover³											
Lodgepole Pine	0	0	0	0	0	1.3	2.4	6.6	6.57	3.61	.09
Spruce	0	0	0	0	0	4.1	4.1	6.4	4.16	1.30	.34
Subalpine Fir	0	0	0	0	0	8.4	2.6	6.4	12.79	1.10	.39
Total	0	0	0	0	0	11.8	9.1	19.4	14.60	5.88	.04
Sub-dominant Trees (2.0-10 m) % Cover³											
Lodgepole Pine	0	0	0	0	0	0	1.0	0.9	0.65	1.48	.30
Spruce	0	0	0	0	0	1.0	1.7	2.0	1.37	0.61	.57
Subalpine Fir	0	0	0	0	0	8.6	7.7	9.3	16.18	0.12	.89
Deciduous	0	0	0	0	0	0	0	0.3	-	-	-
Total	0	0	0	0	0	9.6	10.4	12.4	26.27	0.25	.79
Tall Shrub (0.5-2.0 m) % Cover											
Deciduous	0.4 ^a	0 ^a	0.2 ^a	0.4 ^a	0 ^a	5.6 ^b	4.5 ^b	3.7 ^b	3.39	4.82	.004
Coniferous	0.3 ^a	0 ^a	0.1 ^a	0.3 ^a	0.1 ^a	10.3 ^c	11.2 ^c	18.3 ^d	4.80	32.09	.000
Total	0.6 ^a	0 ^a	0.3 ^a	0.8 ^a	0.1 ^a	15.9 ^c	15.7 ^c	22.0 ^d	12.10	21.21	.000
Low Shrub (woody shrubs up to 0.5 m) % Cover											
Deciduous	3.5	5.6	5.9	8.8	6.0	7.9	16.6	5.0	33.74	1.46	.25
Coniferous	1.1	1.6	1.6	1.4	0.9	3.0	4.3	3.3	1.83	2.51	.06
Total	4.5	7.2	7.4	10.2	6.9	10.8	20.9	8.3	31.44	2.38	.07
Ground Cover %											
Grass	5.4	6.4	2.7	4.0	3.9	1.1	0.4	0.1	9.00	1.79	.16
Fireweed	12.8 ^{ab}	22.9 ^a	16.7 ^a	18.0 ^a	24.8 ^a	0 ^b	0 ^b	0 ^b	81.99	4.03	.01
Other Herb	10.6	10.8	9.1	8.6	14.9	6.8	14.0	7.0	44.52	0.61	.74
Total Herb and Grass	28.8 ^{ab}	40.1 ^a	28.5 ^{ab}	30.5 ^a	43.6 ^a	7.8 ^a	14.5 ^{ab}	7.1 ^a	109.9	5.28	.003
Moss	5.6 ^a	1.0 ^a	2.6 ^a	1.5 ^a	8.7 ^a	47.1 ^b	57.5 ^{bc}	73.2 ^c	123.0	21.40	.000
Downed Wood	7.3	9.2	12.1	9.7	9.4	18.4	19.6	18.0	28.70	2.53	.06
Bare Soil and Rock	6.6	3.9	9.9	9.3	3.6	0.1	0.4	0	26.14	1.86	.14
Snag and Stub (> 15 cm dbh) Density/ha											
Snags within 11-m radius ³	0	0	0	0	0	104.8	80.4	91.5	1732.4	0.26	.78
Stubs within 50-m radius ⁴	0	0.1	8.7 ^a	0.1	9.2 ^a	121.0 ^b	162.3 ^b	0	579.8	31.87	.000
Mean Soil Moisture Regime⁴											
within 11-m radius	0	0.3	0.1	0.2	-0.1	0	0	0.1	0.215	0.30	.94
within 50-m radius	-0.1	0.4	0.3	0.2	-0.2	0	0	0.2	0.137	0.88	.54

¹ Means followed by like superscripts not significantly different at $\alpha = .05$ using Scheffe's test when ANOVA significant ($p < 0.05$).

² CC = Clearcut, SB = Stub Treatment, TI = Tree-Island Treatment, SI = Stubs-and-Islands Treatment, Ti = Tree islands within TI Treatment, SM = Tree Islands within SI Treatment, OG = Old-Growth.

³ ANOVA for snag density and tree cover only tested within Tree-Island portions of treatments and Old-Growth Control.

⁴ Stub density only compared using ANOVA between SB, SI, Ti and SM. Within tree islands, stubs only counted that were within tree islands, and area of each tree island used to develop density estimate.

⁵ xeric = 3, subxeric = 2, submesic = 1, mesic = 0, sub-hgic = -1, hygic = -2, suhygic = -3, hydic = -4.

design. Among the many possible variables, there were relatively few significant differences found, and none of the block means could be shown to be significantly different using Scheffe's multiple comparison test. The full results are not reported here and only those results showing significant differences are outlined below.

Coverage by fireweed was significantly different in the clearcut portions of the different blocks (5516 30%; 5546 19%; 5547 13%). Coverage of low coniferous shrubs (primarily planted seedlings) were significantly different in the clearcut portions of the different blocks, but coverage was generally so low (0.7-1.8%) that this was not likely to effect bird use. Snag density was significantly different between the tree island portions of the different blocks (5516 146/ha; 5546 88/ha; 5547 46/ha) as was the % cover of downed wood (5516 13%; 5546 25%; 5547 18%), and % cover by tall coniferous shrubs (5516 8.7%; 5546 15.0%; 5547 8.6%). Within the Old-Growth Controls, the amount of downed wood was significantly different between the three areas (5516 24% cover; 5546 18%; 5547 11%) as was the cover by sub-dominant subalpine fir trees (5516 16.5%; 5546 5.4%; 5547 5.9%).

4.5.2 Cavity-Nesting Birds

The density of each species of common cavity-nesting bird at each sampled point was examined for correlation with vegetative or physical characteristics within each habitat (clearcut, tree islands or old-growth) where they commonly occurred. Very few significant correlations were found among the many possibilities.

Within the Old-Growth Controls, winter wren densities were positively correlated with increasing herbaceous cover ($r^2 = 0.25$, $F_{1,18} = 6.01$, $P = 0.02$). Winter wren densities were also correlated with increasing soil moisture ($r^2 = 0.20$, $F_{1,18} = 4.66$, $P = 0.04$) but herb cover was correlated with soil moisture ($r^2 = 0.16$) so that the 2 variables may in effect be describing the same habitat factor that was affecting winter wren density.

Within the clearcut areas, the density of black-backed woodpeckers was significantly correlated with stub densities ($r^2 = 0.14$, $F_{1,103} = 16.72$, $P < 0.000$) as was the density of mountain bluebirds ($r^2 = 0.04$, $F_{1,103} = 4.49$, $P = 0.04$). This correlation with stub densities held for black-backed woodpeckers even when only the points in SB and SI treatments were considered ($r^2 = 0.12$, $F_{1,40} = 5.29$, $P = 0.03$). However, the correlation with stub densities did not hold for mountain bluebirds when only the treatments with stubs were considered ($r^2 = 0.006$, $F_{1,40} = 0.24$, $P = 0.63$).

For the red-breasted nuthatch, the best possible explanation of the high variability in densities within tree islands (see Sec. 4.3) appeared to be the difference in tree island sizes in different blocks. Red-breasted nuthatches were only found, or only commonly found, within the experimental treatment areas in Block 5516 which contained the single large (1.4 ha) tree island in the study. This effect was only seen in 1995 when they were detected 16 times in the tree islands of Block 5516. In 1996 they were detected only 5 times in total in tree

islands with some detections made in all Blocks. In 1996, red-breasted nuthatches probably did not breed in any of the tree islands, where they might have bred in the large tree island in Block 5516 in 1995.

4.5.3 Other Birds

I did find vegetative or physical characteristics that may have affected some species and caused relatively high variation that prohibited significant differences from being shown in use of tree islands or Clearcut or Old-Growth Controls (see Sec. 4.3).

The point density of the varied thrush in the Old-Growth Controls was correlated with the average soil moisture regime in the surrounding 50-m radius ($r^2 = 0.195$, $F_{1,19} = 5.22$, $P = 0.03$). The wetter the site, the more likely there were to be varied thrushes on the site. The point density of spruce grouse was positively correlated with the percentage cover of spruce trees ($r^2 = 0.35$, $F_{1,18} = 9.88$, $P = 0.006$). These correlations with habitat factors that were not directly controlled within the experimental design could have led to the high variability that did not allow for significant differences to be found between the habitat factors that were part of the experimental design in Section 4.3.

For the ruby-crowned kinglet and western Wood-pewee, the best possible explanation of the high variability in densities within tree islands (see Sec. 4.3) appeared to be the difference in tree island sizes in different blocks. These two species were only found, or only commonly found, within the experimental treatment areas in Block 5516 which contained the single large (1.4 ha) tree island in the study.

Of the final 4 of the 30 common species not previously mentioned (dark-eyed Junco, MacGillivray's warbler, warbling vireo and pine siskin) for which no significant habitat effect could be shown or surmised, only the dark-eyed Junco appeared to be a true habitat generalist that was found at relatively equal densities in all habitats. Pine siskins tend to flock even during the breeding period and used a variety of habitats. The point densities of MacGillivray's warblers were positively correlated with % cover of tall coniferous shrubs and the % cover of sub-dominant trees (multiple regression: $r^2 = 0.28$, $F_{2,123} = 23.48$, $p = 0.000$) rather than with any of the experimental factors. The point densities of warbling vireos were positively correlated with the percent coverage of tall deciduous shrubs ($r^2 = 0.08$, $F_{1,124} = 10.73$, $p = 0.001$). These habitat elements were not directly controlled within this experiment but did appear to play a part in determining the points at which these species were found.

4.5.4 Bird Communities

The effect of the one larger tree island present in Block 5516 could not have been the entire explanation of the increase in species richness ~~seen~~ in Block 5516, although it may have accounted for the difference in three species mentioned above. The higher species richness of Block 5516 also extended to the Old-Growth Controls in 1995, although this

effect did not persist into 1996. Within the Old-Growth Controls, there appeared to be a negative correlation with the percent coverage by lodgepole pine trees present in the canopy layer ($r^2 = 0.27$, $F_{1,18} = 6.74$, $P = 0.02$). This effect extended to all 3 control areas, i.e. the effects were not confined to any one area. However, Block 5516 had the lowest percent coverage by lodgepole pine (2.4% vs 8.6% and 8.9%) so that the higher species richness in the old-growth areas adjacent to Block 5516 may partly be explained by the lower amounts of lodgepole pine present (or conversely, by the higher proportions of spruce and subalpine fir trees). However, such an effect would not extend into the clearcuts where no trees were present, so this explanation is not entirely adequate for each habitat type.

5.0 DISCUSSION

Both stubs and tree islands were significant factors affecting densities of some species of breeding birds within clearcut areas. The general effect was to raise "diversity" by providing additional habitat elements that could be used by some species that would otherwise be lacking within clearcuts. I will here firstly, consider the actual effects of stubs and tree islands on bird species and then on bird community diversity, secondly, assess the power of the study designs to show the effects of stubs and/or tree islands on bird species and assess the efficiency of the sampling methods used, and finally, assess some of the implications of these results for the mitigation of clearcutting on birds, and in particular on cavity-nesting birds.

5.1 STUB EFFECTS

Using the basic 2x2 ANOVA study design, only the densities of yellow-rumped warblers in clearcuts appeared to be significantly positively affected by the creation of 3-m high stumps (stubs) during clearcutting. However, they were found in all of the treatment types in all of the blocks, so they are clearly not dependent on stubs. Using stepwise regression on the point-by-point data as an alternative method of analysis, the density of yellow-rumped warblers was more strongly correlated with the combined effects of soil moisture regime within 50 m of a point, and the percent coverage by tall coniferous shrubs ($r^2 = 0.43$) than stub density ($r^2 = 0.03$). While stubs can have an effect on yellow-rumped warblers, any method of clearcutting that permits more residual vegetation to be left behind (as in conifer saplings and residual riparian vegetation) will likely benefit yellow-rumped warblers.

Using the basic 2x2 ANOVA study design, the effects of stub creation were not as strong (i.e., $P < 0.20$ but > 0.05 in both 1995 and 1996) for chipping sparrows, black-backed woodpeckers and tree swallows. Having only 3 blocks in this study limited the power of the study design to only showing very strong effects (as previously discussed in Gyug, 1996) so that raising the alpha level of significance can be an acceptable method to show which effects

may be strong when power is so severely limited. However, there was an alternative statistical method to test species responses to stubs using regression techniques applied to the point densities of each species. For species that respond to very local stub densities this may be a more powerful method of analysis than the basic 2x2 ANOVA design that averages species responses over larger areas.

The point-by-point densities of black-backed woodpeckers and mountain bluebirds were significantly correlated with stub densities, but the same did not hold true for chipping sparrows or tree swallows. For black-backed woodpeckers, this correlation even held within the treatments with stubs. Black-backed woodpeckers that both feed on, and nest in stubs appeared to be particularly sensitive to the density of stubs created within a clearcut. Black-backed woodpeckers have been identified as one species that specializes in the habitat that exists after stand-replacing fires (Hutto 1995). Stubs after clearcutting probably at least partially imitate the post-burn habitat, except that stub density is far lower than the density of standing tree boles after a major fire. However, the correlation with stub density did not hold within treatments with stubs for mountain bluebirds, indicating that when the only requirement is for a single nest within a relatively large clearcut, the point-by-point density of mountain bluebirds will not correspond very well with stub densities, but will correlate with the presence or absence of stubs.

Some cavity nests were also found in the stubs (Joy and van den Driessche 1995) and significant numbers of cavity-nesters, as well as other birds, used them as perches or feeding sites (Gyug and Summers 1995). It appears that stubs will be used as intended by birds—for nesting, as foraging perches, as singing perches, and as foraging substrate. However, the net results of stub creation, with statistically detectable positive effects for only a few species, were fairly subtle compared to the much greater effect of tree islands. This is not to diminish the positive effects of stubs simply because they were not useful for as many species as tree islands. Particularly for tree swallows and mountain bluebirds, the positive stub effects for nesting could not be made up for by tree islands because these species prefer open habitats and tree islands had no significant effects for those 2 species.

In 1993, significant stub effects could be shown for tree swallows, woodpeckers (as a group) and for olive-sided flycatchers (Gyug and Summers 1995). The effects of stubs on tree swallows was also found to be positive and significant in 1995 (Gyug 1996) but when the 1995 and 1996 results were taken together, the effects of stubs on densities of tree swallows was not as strong (this document). I did not know the exact locations of tree swallow nests in both years while writing this report but when this data is finally available I suspect that exact nest location could probably be shown to dictate where tree swallows are detected more so than any other factor. Slight differences in nest placement could mean large shifts in which treatments the tree swallows were detected in.

Olive-sided flycatchers were too uncommon in the 1995 and 1996 sampling (10 detections) to analyze the data, although they were detected 21 times in total in 1993 sampling. Within the experimental treatments in 1995 and 1996 they were found only within

the tree islands of the Stubs-and-Islands (SI) treatment replicates indicating that there may still be a stub effect and/or tree island effect as found in 1993. In my experience, olive-sided flycatchers are never very common, and so are not very well sampled within 50-m radius point counts. In addition, the male's territorial advertisement can be heard at a distance of several hundred meters so that transects were probably a more efficient way of sampling their densities. Olive-sided flycatchers have been identified as one of two species (along with black-backed woodpeckers) that specialize in post-fire habitats (Hutto 1995). It is unclear yet whether the combination of tree islands and stubs can replace that habitat because of insufficient data within this study.

Woodpeckers were analyzed as a group in 1993 because so many detections were not positively identified to species. In 1995 and 1996 specific attention was paid to identifying woodpeckers so that species could be analyzed individually. However, only the black-backed woodpecker was sufficiently common to be analyzed within the treatments in 1995 and 1996. In 1993, northern flickers and pileated woodpeckers were counted occasionally within surveys, but neither were detected on the point counts in 1995 although northern flickers were detected 3 times in the tree islands in 1996. 29 of 82 black-backed woodpecker detections in 1995 and 1996 were outside of tree islands with 15 of those 29 observations associated with stubs or nests. All 15 three-toed woodpecker and 7 of 10 hairy woodpecker detections in the treatments in 1995 and 1996 were in tree islands, with most associated with nest locations. Two of the 3 hairy woodpecker observations outside of tree islands were on stubs. It appears that woodpeckers make more use of tree islands than stubs where both are available, but that stubs will be used where available, and particularly by black-backed woodpeckers.

This study looked at stub use within the ESSFmv3 biogeoclimatic zone. If the results are to have any applicability outside this zone, we must examine the results of other studies to look for common patterns or trends. Some studies have concentrated on actual use of the stubs by birds (e.g. Morrison 1992) but I am presently aware of only one other study statistically examining breeding bird densities in relation to stubs, and one study consisting of anecdotal records. Bennett (1994) examined 4 densities of stub-retention (0, 3, 10 and 30 stubs/ha) in the Okanagan Highlands of the southern interior. He showed a stub effect for mountain bluebirds with significantly higher densities in clearcuts with stubs, than in clearcuts without stub. At Donna Creek, we found a significant stub effect for mountain bluebirds in 1993, but the effect was not as strong (and not significant at $\alpha=0.05$) in 1995 or 1996. Tree swallows were not common in the Okanagan Highlands study, so that the highly positive effect that stubs had on tree swallows in 1993 and the slight effect in 1995 and 1996 at Donna Creek could not be compared with the other study. The black-backed woodpecker was not present in the Okanagan study sites so that the response of this species to stubs could not be compared. In an anecdotal study, Harris (1996) studied a lower elevation clearcut with stubs in the Okanagan and found tree swallows, northern flickers, western bluebirds, hairy woodpeckers, mountain chickadees and red-breasted nuthatches nesting in stubs within a clearcut.

5.2 TREE ISLAND EFFECTS

The most significant use of small tree islands was by 5 species (American robin, black-backed woodpecker, chipping sparrow, Wilson's warbler and yellow-rumped warbler; see Table 9) that were also commonly found in the clearcut areas surrounding the small tree islands. This may be a characteristic of such small islands—they form excellent habitat for species with relatively plastic habitat requirements, but form relatively poor habitat for species that rely almost solely on forest cover as habitat (since they may be too small to contain entire breeding territories, see below). This was also found by Loman and von Schantz (1991) comparing small forest islands to larger islands over a range from 0.01-24.0 ha in an agricultural mosaic in Sweden. Diversity relative to habitat area may increase in the very small habitat islands, but the increase is made of species that rely on the surrounding fields for foraging, not from typical woodland species which are usually absent from these small islands.

Nineteen of the 30 common bird species used for analyses in Tables 9 and/or 10 were what I would term "forest" species, based on densities in forests compared to clearcuts within this study (Table 11). Five would be considered "clearcut" species, five would be considered "island" species and one, the dark-eyed Junco, could be considered a true generalist.

Of the 19 forest species, about three-quarters (15 of 19) of the species were never found, or very uncommonly found, in the small tree islands (Table 11). For these 15 species, tree islands of 0.18-0.40 ha will simply not be large enough to provide suitable breeding habitat within a clearcut. The white-winged crossbill and Tennessee warbler could be added to this list based on the 1993 sampling (Gyug and Summers 1995) but these 2 species were too uncommon to analyze within the 1995 and 1996 sampling. The white-winged crossbill was not detected at all within the 1995 and 1996 sampling, and Tennessee warbler detected only once in the Old-Growth Controls.

The small size of the tree islands may have been the single most important factor affecting the habitat suitability for some of these forest species. The red-breasted nuthatch and ruby-crowned kinglet only made common use of tree islands in Block 5516, where the single largest 1.4-ha tree island was located. Red-breasted nuthatches in southern B.C. were observed combining several small tree patches (< 1 ha) about 200 m apart into single breeding territories (Gyug and Bennett 1996).

Table 12. General habitat affinities of the common bird species in the Donna Creek study area.

Island Species
(max. density in tree islands)
American Robin
Black-backed woodpecker
Chipping sparrow
MacGillivray's warbler
Wilson's warbler

Generalist Species
(common in all habitats)
Dark-eyed Junco

Clearcut Species
(only found in clearcuts)
Golden-crowned sparrow
Lincoln's sparrow
Mountain bluebird
Savannah sparrow
Tree swallow

Forest Species:
commonly using tree islands
Pine siskin
Swainson's thrush
Three-toed woodpecker
Yellow-rumped warbler

Forest Species:
rarely found in tree islands
Blackpoll warbler
Boreal chickadee
Brown creeper
Evening grosbeak
Golden-crowned kinglet
Gray jay
Hammond's flycatcher
Northern Waterthrush
Pine grosbeak
Red-breasted nuthatch
Ruby-crowned kinglet
Spruce grouse
Townsend's warbler
Varied thrush
Winter wren

Different species will require different sizes of tree islands to form suitable breeding territories. The smallest tree island that will be suitable for Townsend's warblers appeared to be 0.8 ha in southern B.C. (Gyug and Bennett 1996). The effect of tree island size on Townsend's warblers may be similar across a broad geographical range since none established breeding territories in any of the 21 small tree islands at Donna Creek or in the small tree islands in southern B.C. (Gyug and Bennett 1996). Gray jays were commonly found in the 0.3-4.3 ha tree islands in southern B.C. (Gyug and Bennett 1996) but were absent from the very small tree patches in the Donna Creek study area. I do not specifically know why the pattern is not common among the study areas, but by the time of breeding bird sampling in May and June, gray jay young have already fledged and they may wander fairly widely contributing to high variability in count numbers, and perhaps habitat use. Varied thrushes were detected only twice in the 1.4-ha tree island at Donna Creek in 1995, and almost certainly did not breed in that tree island, and were not detected in any tree islands in 1996. They were also very uncommon in the 0.75-4.3 ha tree islands in southern B.C. so they probably require tree islands at the high end of this range, or larger, to establish breeding territories. Solitary vireos and western tanagers appeared to require at least 2.1 ha (Gyug and Bennett 1996). Solitary vireos and western tanagers were present in the Donna Creek study area but both were too uncommon to determine any tree island size effects at Donna Creek.

Several species probably require larger tree island sizes than any of those in either the Donna Creek study or the southern B.C. study of Gyug and Bennett (1996). Brown creepers and boreal chickadees did not use the tree islands in either study (but were found in the adjacent forests) so that larger habitat islands will have to be considered for management of these species. Brown creepers apparently require territory sizes larger than the tree islands examined. Brown creepers had breeding territory sizes of 2.3-6.4 ha in Michigan (Davis 1978), and the very similar treecreeper (*Certhia familiaris*) was absent from forest patches of less than 10 ha in Sweden (Loman and von Schantz 1991). Clearly, on the short-term within clearcuts, small tree islands will not serve these species.

The Donna Creek breeding bird surveys were directed at diurnal passerines and so did not sample breeding owls well. However, a boreal owl was detected on Old-Growth Control plots in 1995 although boreal owls were never detected in the tree islands, either in the plot samples or in incidental observations. A northern pygmy owl was detected once in the old-growth forest and a northern hawk owl detected once in a tree island. Where surveys in other areas have specifically targeted owls, boreal owls, as well as northern saw-whet owls and barred owls, were not detected in tree islands, but were present in the nearby forest (Gyug and Bennett 1996). To reliably detect breeding owls, surveys would have to be conducted at night and in the appropriate season, which is usually earlier in the year than the passerine bird breeding season.

Three-toed and hairy woodpeckers nested in some small tree islands at Donna Creek, but appeared to be foraging almost entirely in the adjacent old-growth forest rather than in other tree islands or in the clearcut habitats surrounding the tree islands. If old-growth forest

had been unavailable adjacent to the experimental cutblocks, these 2 species may not have used the tree islands for nesting. Through the next timber-harvest passes, the adjacent old growth forests may not be available, and the forest within the clearcut may not have regenerated to the point where it again has become suitable breeding habitat. In the southern interior of B.C., regenerating managed forest even 25 years after clearcutting is still very poor woodpecker habitat (Gyug and Bennett 1996). If the intent of these tree islands is to provide long-term nesting habitat for woodpeckers, then timber-harvesting techniques need to be developed that allow for these species to establish stable populations that are not dependent on adjacent old-growth habitat to sustain them. Small tree islands may serve as suitable nesting sites but appear unable to meet foraging requirements of hairy and three-toed woodpeckers.

5.3 BIRD COMMUNITIES

The effect of both stubs and tree islands was to increase the number of species present compared to a clearcut. Species richness was higher in the TI and SI treatments because of the presence of tree islands: when the tree island points were excluded from the results, species richness in these treatments was not different from species richness in clearcuts. However, this result is not entirely unexpected since any creation of patchiness in an otherwise uniform habitat should increase species richness (Wiens 1989b:128). The overall effect of tree islands on total bird density within a clearcut treatment was insignificant in 1995, but significant in 1996. This change between the 2 years appeared to result not from an increase in densities in tree island treatments but from a relatively greater decrease in the clearcut treatments that did not contain tree islands. Total bird densities were 18% and 14% lower in the TI and SI treatments respectively in 1996 than in 1995, and 26% and 24% lower in the CC and SB treatments respectively in 1996 than in 1995 (see Table 7). Looking just at the tree islands themselves, total bird densities dropped only 14% within the tree islands between 1995 and 1996, but dropped 21% in the Clearcut Controls and 29% in the Old-Growth Controls (see Table 9). At this point we do not know why numbers appeared to be slightly more stable in the tree islands than in any of the other clearcut or forest habitats. Since long-term monitoring of bird populations is not planned on an annual basis in the Donna Creek project, the data to determine if this trend will continue will not be available.

5.4 POWER OF THE STUDY DESIGNS

The most powerful assessment of breeding bird densities in tree islands appeared to be from the analysis that examined tree islands as separate habitats. The 2x2 ANOVA study design and the old-growth to treatment contrast that both lumped the tree islands in with the surrounding matrix of clearcut area as an overall treatment mean appeared to do statistical disservice to the birds that actually did use the tree islands. When the tree islands only occupied less than 5% of the treatment replicate area, the density of a given forest species in the tree islands would have to be 20 times higher than in old-growth forest to reach an

equivalent density when averaged over the area of the clearcut around the tree islands. This was clearly not likely. However, by assessing the tree islands as a habitat unto themselves, a clearer picture emerged of which species were found establishing breeding territories within them, and whether this density was greater or less than in clearcuts or old growth forests.

The assessment of the effect of stubs using the 2x2 ANOVA study design was found to be fairly limited in its resolving power because of generally low densities of cavity nesting birds, because of high variability in their occurrence, and because only 3 replicate blocks were available. For instance, even though mountain bluebirds only occurred in treatment units where dispersed stubs occurred, the 2x2 ANOVA design could not show any significant effect. However, using the point data, rather than summing or averaging the points over the treatments in which they occurred, there was a significant correlation between stub density and mountain bluebird density. The typical cavity nesters that use open country (e.g. bluebirds, swallows, American kestrel) are strong fliers and can cover a lot of territory very quickly. Nest searches and absolute densities based on nesting pairs may be more informative of the real reaction of these species to stubs in clearcuts.

Dunnett's test was found to be relatively powerful to detect differences for even relatively uncommon birds found in the Old-Growth Controls that were less abundant in the experimental treatments. However it was relatively weak for birds that were essentially absent from the Old-Growth Controls but common (or limited to) the experimental treatment areas. Dunnett's test could not show 4 of the 5 common species that were absent from the Old-Growth Controls (golden-crowned sparrow, savannah sparrow, mountain bluebird and tree swallow) to be statistically more common in any of the experimental treatments than in the Old-Growth Controls. Only for the Lincoln's sparrow (with 634 bird detections) could this test find them to be more abundant in any of the experimental treatments. Consequently, Dunnett's test could only be relied on for species showing a negative response in density to clearcuts and/or the experimental treatments compared to the Old-Growth Controls. This fairly limits its application to this breeding bird data because it means that it can only be relied on as a one-tailed test in examining old-growth to treatment differences.

5.5 ASSESSMENT OF SAMPLING METHODOLOGIES

It would appear that some generally uncommon species were not as well sampled by 100-m diameter point count plots in 1995 and 1996 as by 150-m width transect plots in 1993 (see discussion for olive-sided flycatchers, sec. 5.1). This indicates the trade-off made in sampling smaller areas in a more rigorous manner, compared to sampling larger areas with their higher potential for bias. The bias on transects can be caused by many factors such as distractions to observers because of navigational difficulties while traversing rough terrain, variations in detection densities because time-effects are not as rigidly controlled on transects, and that bird detections will drop off sharply at distances even less than 75-m from the observer for many species (e.g. Roeder et al. 1987). Point sampling was also necessary here to counter the effects of differing bird detectability within forested and non-forested

habitats, and to sample the tree islands efficiently. While spot mapping of breeding birds may have worked as well as point counts to counter differences in detectability in different habitats, the large treatment areas involved in this study could not have been covered.

Nest searches were not reported here (see Joy, in prep.) but are an integral part of understanding how cavity-nesting birds use these tree islands and clearcuts with stubs. Point counts are relatively poor at determining the usefulness of stubs to strong and swift-flying birds such as tree swallows where the only requirement of stubs is for a nesting site. However, point counts were relatively good at determining the usefulness of stubs to black-backed woodpeckers where they used them for foraging and for nesting.

Some bird species showed significant annual fluctuations in their densities in the Donna Creek study area. Using the data from Tables 5-9, American robins, Lincoln's sparrows, MacGillvray's warblers, black-backed woodpeckers, evening grosbeaks, pine grosbeaks and pine siskins were all more common in 1995 than in 1996. Densities of all birds was also higher in 1995 than in 1996. Only Wilson's warbler was more common in 1996 than in 1995. Between 1995 and 1996 there were probably very few changes in vegetation or physical characteristics on the study sites so that these population fluctuations are probably due to factors beyond the control of this experiment. However, between the interim analysis based on only 1995 data (Gyug 1996) and the final analysis based on the two years data (this document), the basic interpretations did not change for any of these species. The only interpretations that did change were for species which did not show significant fluctuations from year to year including red-breasted nuthatches and tree swallow, both of which are cavity-nesting birds.

The value of repeating the sampling in two consecutive years appears to lie in strengthening the conclusions for species which did show positive responses to stubs or tree islands. The value was not to show significant population fluctuations in any particular species of bird since there is no longer term base to compare these to. In 1995, tree swallows showed a positive response to the stub effect in the 2x2 ANOVA design and red-breasted nuthatches showed quite a bit of tree island use particularly in Block 5516 with the larger tree island. These responses were not evident in the 1996 sampling, so that if there had been only one year of sampling, and that year was 1996, it would have been hard to interpret the data for these particular species. Repeating sampling in two breeding seasons provides some measure of protection against the experimental design being defeated by the irregular population fluctuations of any given species.

5.6 MANAGEMENT IMPLICATIONS FOR TIMBER HARVESTING

Stubs in clearcuts appear to be particularly useful for black-backed woodpeckers and to be probably essential for tree swallows and mountain bluebirds. Mountain bluebirds did not appear to make much use of the tree island treatments, even when the tree islands were ringed by stubs, so that dispersed stubs throughout clearcuts will be particularly important as a mitigation method for this species that prefers very open habitats. Based on the data in this study, where stub densities averaged 8-10/ha in each replicate, I cannot definitively recommend one density of stubs over another for use as bird nesting habitat, except to say that not every block or replicate was used for nesting by tree swallows and mountain bluebirds, so that higher stub densities may be more appropriate. Bennett (1994) only found nesting when stub densities approached 30/ha in southern B.C. Studies that look at a variety of stub densities over a larger number of clearcuts than in the Donna Creek study would be required to find any "optimal" stub density to mitigate the effects of clearcutting on cavity-nesting birds.

Given that the tree swallows and mountain bluebirds are secondary cavity nesting species, there may be very few actual nesting opportunities even though stubs may appear relatively abundant. The only primary cavity nesting bird that was common in the stub treatments was the black-backed woodpecker. Over the range of stub densities studied here (2-15/ha), higher densities of stubs provided better foraging opportunities and enhanced habitat use for black-backed woodpeckers than the lower densities. Encouraging foraging use of stubs in clearcuts by black-backed woodpeckers should also encourage cavity creation for nesting or roosting so that secondary cavity nesters can make use of the stubs.

Tree islands of 0.18-0.40 ha were of little use to most of the forest bird species at Donna Creek even 4-5 years after clearcutting. Tree islands would have to be larger than 0.4 ha to provide habitat mitigation for a wider variety of bird species. It appears that small tree islands may be used in conjunction with larger islands to provide useful habitat for a few forest species—particularly red-breasted nuthatches and ruby-crowned kinglets. Data from other studies in southern B.C. indicates tree islands should be 2 ha or larger to provide more habitat for more forest species.

Both stubs and small tree islands in clearcuts will be used by some cavity-nesting species for foraging, and they will be essential for nesting of some species within clearcuts. Both techniques can be used, at least partially, to mitigate the loss of wildlife trees during clearcutting for some species. Larger tree islands (2 ha or greater) and higher densities of stubs (15/ha or greater) appear to provide better mitigation than smaller tree islands and lower stub densities.

6.0 RECOMMENDATIONS FOR FUTURE SAMPLING AT DONNA CREEK

The point count methods used in 1995 and 1996 should be repeated without change whenever this project is revived in the future to monitor long-term trends. These should be conducted together with nest searches for cavity-nesting birds. Nest searches should be considered the primary data source of breeding density with point counts used as an adjunct to determine how stubs and tree islands are affecting other bird species, and to better determine the usefulness of stubs to some bird species as the clearcuts regenerate into a managed forest. The point count method allows correlation with vegetative factors beyond the basic factors that were entered in the experimental design. As vegetation regrows following clearcutting, using a method that will allow for this effect will have a distinct advantage over other methods.

In the future, breeding bird studies at Donna Creek should also be conducted for two successive years whenever the area is being resampled. As shown here, there was considerable interyear variation, and using a second year of data both reduces the chance of accepting a correlation that, in the final analysis, was not as strong as first thought, and of seeing bird responses to the stubs and tree islands that are not necessarily exhibited in every year.

The Donna Creek study area should be resampled for cavity-nesting birds in about 10 years time (2006). At that time, the clearcuts should be at, or near, green-up with conifers typically at 3 m height. Based on experience in the regenerating clearcuts in the ESSF in southern B.C., I would expect that the breeding avifauna would start to show many differences to the avifauna studied here just after clearcutting. Cavity-nesting birds of open areas such as mountain bluebirds and tree swallows may have disappeared while other cavity-nesting birds such as chickadees may start using the stubs in the clearcuts for nesting. Study at 10-15 year intervals after that may show smaller changes in the overall avifauna after conifers are well established on the site.

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Appendix 1. The number of singing bird detections by species for each control and treatment replicate. The 3 figures are for Cutblocks 5516, 5546 and 5547 respectively, except for Clearcut Controls, Blocks 5510, 5549 and 5550. Where all 3 were zero, a single "0" has been substituted. Data for 1995 is followed by the data for 1996 directly underneath. For treatment units with tree islands, detections within tree islands are presented separately. Total effective sampled area in a replicate is the product of 7 visits x the actual physical area sampled (i.e. 7 points x 0.7854 ha except in tree islands).

	Old-Growth Control OG	Clearcut Control CC	Clearcut Treatment CT	Stub Treatment SB	Tree Island (TI) Treatment		Stubs-and-islands (S Treatment	
					Outside Islands	In Tree Islands	Outside Islands	In Tree Islands
Total Effective Sampled Area (ha)								
5516	38.5	38.5	38.5	38.5	38.5	15.2	38.5	7.8
5546	38.5	38.5	38.5	38.5	38.5	6.0	38.5	6.7
5547	38.5	38.5	38.5	38.5	38.5	7.1	38.5	7.8
Species								
Alder flycatcher	0	10,0,0	0	0,0,3	0	0	0,1,0	0
	0	7,0,0	0	0,0,1	0	0,0,2	0	0
American redstart	0	0	0	0	0	0	0	0
	0	2,0,0	0,1,0	0	0	0	0	0
American robin	7,4,0	1,8,1	3,0,2	10,2,0	1,0,8	5,1,4	2,4,6	2,3,5
	2,3,1	2,1,0	2,0,1	2,1,0	0,1,2	4,3,6	2,1,0	4,1,5
Black-backed woodpecker	0	0	0	0	0	0	0	0
	1,0,0	0	0	0	0	0	0	0
Blackpoll warbler	18,24,20	0	0	0	0	0	0	0
	17,15,29	0	0	0	0	2,0,0	0	1,0,2
Boreal chickadee	1,0,0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
Boreal owl	1,0,0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
Brewer's blackbird	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0,1,0	0
Brown creeper	1,3,5	0	0	0	0	0	0	0
	0,4,1	0	0	0	0	0	0	0
Cedar waxwing	0	0	0	0	0	0	0	0
	1,1,0	1,0,0	0	0	0	0	0	0
Chipping sparrow	5,4,4	1,17,1	8,4,3	7,6,4	8,3,2	19,5,14	3,6,9	16,5,11
	0,0,1	9,8,3	2,12,5	5,11,6	4,4,0	3,2,6	5,10,11	7,3,9
Common snipe	0	0	0	4,0,0	0	0	0	0
	0,0,1	0	0	0	0	0	0	0
Dark-eyed junco	14,9,16	12,23,22	31,12,14	13,9,7	13,14,11	7,4,5	14,14,7	5,2,3
	11,4,8	14,13,9	6,8,15	23,11,13	12,16,5	9,2,9	11,12,9	6,2,3
Dusky flycatcher	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0,1,0	0
Evening grosbeak	0,1,0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0,1,0
Fox sparrow	0	0	0	0	0	0	0	2,0,0
	0	0	0	0	0	0	0	0
Golden-crowned kinglet	24,20,14	0	0	0	0	0	1,0,0	0
	20,29,14	0	0	0	0	0	0	0
Golden-crowned sparrow	0	2,0,0	1,0,0	11,0,0	2,0,0	0	4,0,0	0
	0	2,1,7	1,0,0	5,0,0	4,0,0	2,0,0	3,0,0	1,0,0
Gray jay	0	0	0	0	0	0	0	0
	1,0,0	0	0	0	0	0	0	0,0,1

Appendix 1. (continued)

	Old-Growth Control OG	Clearcut Control CC	Clearcut Treatment CT	Stub Treatment SB	Tree Island (TI) Treatment		Stubs-and-Islands (SI) Treatment	
					Outside Islands	In Tree Islands	Outside Islands	In Tree Islands
Hammond's flycatcher	3,1,6	0	0	0	0	0	0	0
	0,0,4	0	0	0	0,1,0	1,0,0	0	0,1,0
Hairy woodpecker	0	0	0	0	0	0,0,1	0	0
	0	0	0	0	0	0	0	0
Hermit thrush	0,3,0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
Least flycatcher	0	0	0	0	0	0	0	0
	0	0	0,1,0	0	0	0	0	0,0,1
Lincoln's sparrow	0	61,38,49	31,36,33	21,24,33	22,33,66	0,2,3	28,43,25	3,1,3
	0	31,21,22	21,16,15	21,23,13	11,17,26	0,1,2	22,22,15	0,0,2
MacGillivray's warbler	5,0,2	7,8,1	4,0,0	0	0,3,1	4,3,9	0,1,1	0,1,4
	0	6,4,0	3,0,1	0,3,6	1,5,3	0,0,3	0,1,6	1,2,5
Mountain bluebird	0	0	3,0,0	0	0	2,0,0	0	1,0,0
	0	0	0	0	0	1,0,0	0	1,0,0
Northern waterthrush	4,0,4	0	0	0	0	0	0	0
	3,1,1	0	0	0	0	0	0	0
Northern pygmy owl	0	0	0	0	0	0	0	0
	0,1,0	0	0	0	0	0	0	0
Orange-crowned warbler	0,0,4	3,0,0	0,2,0	0	0	2,0,1	0	0
	0	1,0,0	0	0	2,0,0	3,0,0	0	1,0,1
Olive-sided flycatcher	2,0,1	0	0	0	0	0	0	2,0,1
	0	0	0	0	0	0	0	0,1,2
Pine grosbeak	6,2,1	0	0	0	0	3,0,0	0	2,0,0
	2,0,0	0	0	0	0	0	1,0,0	0
Pine siskin	3,5,2	0,0,1	0	5,1,0	0	7,1,0	1,0,0	4,3,5
	2,1,0	1,0,0	0,1,0	0	0	8,0,0	0	5,0,1
Pacific-slope flycatcher	0	0	0	0	0	0	0	0
	0,1,0	0	0	0	0	0	0	0
Red-breasted nuthatch	10,10,11	0	0	0	0	12,0,0	0	4,0,0
	4,7,4	0	0	0	0	1,0,1	0	1,1,2
Ruby-crowned kinglet	9,15,14	0	0	0	0	10,0,0	0	3,0,0
	7,8,2	0	0	0	0	12,0,0	0	0
Savannah sparrow	0	41,13,21	8,40,1	4,25,7	1,3,18	0	7,6,6	0
	0	17,3,27	11,12,10	5,20,5	3,5,10	0	9,3,6	0
Solitary sandpiper	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0,1,0	0
Solitary vireo	2,0,0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
Spruce grouse	1,0,0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
Spotted sandpiper	0	0	0	0	0	0	0	0
	0	0	0	0,0,1	0	0	0	0
Swanson's thrush	20,20,10	0	0	0	0	5,0,2	0	2,1,2
	9,9,5	0	0	0	0	7,1,0	0	2,1,1
Tennessee warbler	0	0	0	0	0	0	0	0
	0,0,1	0	0	0	0	0	0	0
Townsend's warbler	59,56,37	0	0	0	0	0,0,1	0	0,0,1
	33,43,28	0	0	0	0	3,1,1	0	0,1,1
Tree swallow	0	0	0	0	0	0	0	0
	0	2,0,0	0	0	0,0,1	1,0,1	0	0

Appendix 1. (continued)

	Old-Growth Control OG	Clearcut Control CC	Clearcut Treatment CT	Stub Treatment SB	Tree Island (TI) Treatment		Stubs-end-Islands (SI) Treatment	
					Outside Islands	In Tree Islands	Outside Islands	In Tree Islands
Unidentified warbler	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0,1,0
Varied thrush	12,1,2	0	0	0	0	2,0,0	0	1,0,0
	6,0,0	0	0	0	0	0	0	0
Warbling vireo	1,1,1	6,0,0	0	0	0	0,0,1	0	1,1,0
	3,0,0	5,0,0	0	0	1,0,0	5,0,0	0	0
White-crowned sparrow	0	0	1,0,0	4,0,0	0	2,0,0	1,1,1	0
	0	3,4,1	1,0,0	0,0,1	1,0,0	0	0	0
Western flycatcher	0	0	0	0	0	0	0	0
	0,0,2	0	0	0	0	0	0	0
Western tanager	0	0	0	0	0	0	0	2,0,0
	0	0	0	0	0	0	0	0
Wilson's warbler	13,21,9	2,23,0	5,0,1	10,0,9	8,1,1	17,8,15	1,0,0	13,5,22
	12,2,11	14,20,2	5,2,4	9,0,7	9,13,7	25,12,19	7,2,5	15,15,26
Winter wren	15,1,4	0	0	0	0	0	0	0
	11,7,11	0	0	0	0	0,3,0	0	0
Western wood-pewee	0,0,3	0	0	0	0	4,0,0	1,0,0	5,0,1
	0	0	0	0	0	3,0,1	0	1,0,1
Yellow warbler	0	0	0,0,1	0	0	0	0	0
	0	0	0	0	0	0	0	0
Yellow-rumped warbler	21,19,38	2,5,0	4,0,1	5,2,5	0,0,1	30,4,6	2,3,2	16,6,14
	14,20,19	8,2,1	1,1,2	4,5,1	1,0,1	20,10,9	4,2,0	14,7,7

Appendix 2. The number of all bird detections by species for each control and treatment replicate. The 3 figures are for Cutblocks 5516, 5546 and 5547 respectively, except for Clearcut Controls, Blocks 5510, 5549, 5550. Where all 3 were zero, a single "0" has been substituted. For treatment units with tree islands, detections within tree islands are presented separately.

	Old-Growth Control OG	Clearcut Control CC	Clearcut Treatment CT	Stub Treatment SB	Tree Island (TI) Treatment		Stubs-and-Islands (SI) Treatment	
					Outside Islands	In Tree Islands	Outside Islands	In Tree Islands
Alder flycatcher	0	11,0,0	0	0,0,4	0	0	0,1,0	0
	0	10,0,0	0	0,0,3	0	0,0,2	0	0
American kestrel	0	0	0,0,1	0	0,2,3	0,1,2	0,3,0	0,0,1
	0	0	1,0,0	0	0,0,1	0	0	0
American pipit	0	0	0	0,3,0	0	0	0	0
	0	0	0,6,0	0	0	0	0	0
American redstart	0	0	0	0	0	0	0	0
	0	2,0,0	0,1,0	0	0	0	0	0
American robin	19,9,3	21,16,20	18,11,12	42,30,5	24,8,23	32,15,8	30,13,18	16,9,22
	13,8,5	17,14,16	14,3,10	30,18,6	23,7,16	18,10,11	20,23,17	14,8,17
Black-backed woodpecker	1,1,0	0	1,0,0	6,2,0	2,1,1	17,3,0	2,3,2	2,2,12
	1,1,4	0	0	6,0,0	0,0,1	8,0,0	2,0,1	2,1,6
Blue grouse	0	0	0	0	0	0	0	0
	0	0,1,0	0	0	1,0,0	0	0	0
Blackpoll warbler	19,24,20	0	0	0	0	0	0	1,0,0
	22,17,33	0	0	0,1,0	0	2,0,1	0	1,0,2
Boreal chickadee	5,1,2	0	0	0	0	0	0	0
	4,6,0	0	0	0	0	0	0	0
Boreal owl	1,0,0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
Brewer's blackbird	0	0	0	0,2,0	0	0	0	0
	0	1,0,0	0	0,1,0	0,1,0	0	0,5,0	0
Brown creeper	2,4,5	0	0	0	0	0	0	0
	0,4,1	0	0	0	0	0	0	0
Cedar waxwing	0	0	0	0	0	0	0	0
	1,1,0	1,0,0	0	0	2,0,0	0	0	0
Chipping sparrow	5,4,4	3,20,3	15,6,8	10,7,5	12,5,4	26,7,22	5,7,11	21,8,15
	0,0,1	14,15,4	4,15,9	7,21,10	8,10,3	5,8,8	12,13,16	17,3,14
Common nighthawk	0	0	0	0	0,0,1	0	0	0
	0	0	0	0	0	0	0	0
Common raven	0,0,1	0	0,0,1	0	0,0,1	0,0,1	0,0,2	0
	0,0,5	0	1,0,0	0,0,3	1,0,0	0	0	0
Common snipe	0	3,0,0	1,0,0	9,0,0	0	1,0,0	3,0,1	0
	0,0,1	1,0,0	0	0	0	0	0	0
Dark-eyed junco	20,20,34	31,60,38	66,38,45	69,30,49	57,47,57	21,18,29	46,43,54	17,21,25
	13,11,11	28,34,18	34,25,39	57,34,38	50,48,26	21,9,12	35,43,27	17,10,14
Dusky flycatcher	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0,1,0	0
Empidonax flycatcher sp.	0	0	0	0	0	0	0	0,1,0
	0	0	0	0	0	0	0	0
Evening grosbeak	5,6,2	0	2,2,0	1,8,0	2,1,0	0	0,1,0	0
	3,1,3	0,0,1	0	0	1,0,0	0	0	0,2,0
Fox sparrow	0	0	0	0	0	0	0	2,0,0
	0	0	0	0	0	0	0	0
Golden-crowned kinglet	30,33,27	0	0	0	0	0	1,0,0	0
	35,40,30	0	0	0	0	1,0,0	0	0,1,0

Appendix 2. (continued)

	Old-Growth Control OG	Clearcut Control CC	Clearcut Treatment CT	Stub Treatment SB	Tree Island (TI) Treatment		Stubs-and-Islands (S) Treatment	
					Outside Islands	In Tree Islands	Outside Islands	In Tree Islands
Golden-crowned sparrow	0	2,0,0	1,0,0	11,0,0	2,0,0	0	7,0,0	1,0,0
	0	2,1,7	6,0,0	5,0,0	6,0,0	2,0,0	10,0,0	2,0,0
Gray jay	15,13,7	0	0	1,0,0	0	0	0	0
	10,15,18	0	0	0	0,2,1	0,0,6	0	1,4,4
Hammond's flycatcher	3,1,8	0	0,1,0	0	0	0	0	0
	0,1,6	0	0,0,1	0	0,1,0	1,0,0	0	0,1,0
Hairy woodpecker	4,0,0	0,1,0	0	0	0,0,1	0,0,7	0	0
	1,0,0	0	0	0	0	0	2,0,0	0
Hermit thrush	1,5,0	0	0	0	0	1,0,0	0	0
	0	0	0	0	0	0	0	0
Least flycatcher	0	0	0	0	0	0	0	0
	0	0	0,1,0	0	0	0	0	0,0,1
Lincoln's sparrow	0	93,68,82	55,55,69	27,47,54	42,70,95	0,4,8	47,65,50	5,2,5
	0	77,38,52	37,39,26	36,44,36	21,38,62	0,3,6	40,52,29	1,1,7
MacGillivray's warbler	5,0,2	7,8,1	4,0,0	0	0,3,1	4,3,9	0,1,1	0,1,4
	0	6,4,1	3,0,1	0,3,6	2,6,3	0,0,6	0,1,6	1,2,5
Mountain bluebird	0	0,2,0	12,0,1	12,10,0	3,0,0	5,0,0	18,0,0	4,1,0
	0	0,4,0	6,0,2	2,1,0	4,0,0	3,0,0	14,1,0	5,0,0
Northern hawk owl	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0,1,0
Northern flicker	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	3,0,0
Northern waterthrush	4,0,4	0	0	0	0	0	0	0
	3,1,1	0	0	0	0	0	0	0
Northern pygmy owl	0	0	0	0	0	0	0	0
	0,1,0	0	0	0	0	0	0	0
Orange-crowned warbler	0,0,4	3,0,0	0,3,0	1,0,0	0	2,0,1	0	0
	0	2,0,0	0	0	2,0,0	3,0,0	0,0,1	1,1,1
Olive-sided flycatcher	2,0,1	0	0	0	0	0	0	2,0,1
	0	0	0	0	0	0	0	0,1,3
Pine grosbeak	6,3,1	0	1,0,0	1,0,0	1,0,0	3,0,2	1,0,0	4,0,0
	2,0,0	0	0	0	0	3,0,0	2,0,0	0
Pine siskin	29,48,26	15,18,29	32,14,19	46,28,11	28,14,13	38,5,5	35,23,13	30,9,20
	3,4,4	12,7,5	10,40,1	18,14,4	10,2,4	14,1,0	8,3,4	9,1,1
Pacific-slope flycatcher	0	0	0	0	0	0	0	0
	0,1,0	0	0	0	0	0	0	0
Red-breasted nuthatch	11,12,12	0	0	0	0	14,0,0	0	9,0,0
	5,9,4	0	0,0,1	0	0	1,0,1	0	1,1,2
Ruby-crowned kinglet	10,17,17	0	0	0	0	13,0,0	0	5,0,0
	8,8,3	0	0	0	0	12,0,0	0	0
Red crossbill	0,1,0	0	0,0,1	1,0,1	0,2,0	0	0	0
	1,0,0	0	0	0	0	0	0	0
Red-tailed hawk	0	2,0,0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
Ruffed grouse	0	0	0	1,0,0	0	0	0	0
	0	0	0	0	0	0	0	0
Say's phoebe	0	0	0	1,0,0	0	0	0	0
	0	0	0	0	0	0	0	0
Savannah sparrow	0	50,19,31	9,50,1	6,27,7	1,8,20	0	7,7,8	0
	0	22,4,34	12,18,16	7,22,7	3,9,14	0	9,5,8	0
Solitary sandpiper	0	1,0,0	0	2,0,0	0	0	2,0,0	0
	0	2,0,0	0	1,1,0	0,1,0	0	0,1,0	0

Appendix 2. (continued)

	Old-Growth Control OG	Clearcut Control CC	Clearcut Treatment CT	Stub Treatment SB	Tree Island (TI) Treatment		Stubs-and-Islands (SI) Treatment	
					Outside Islands	In Tree Islands	Outside Islands	In Tree Islands
Solitary vireo	2,0,0	0	0	0	0	1,0,0	0	0
	0	0	0	0	0	0	0	0
Spruce grouse	4,1,6	0	0	0	1,0,0	0	1,0,0	1,0,1
	7,1,0	0	0,1,0	0	0	0,0,1	0	1,0,0
Spotted sandpiper	0	0	0	3,0,1	1,0,0	0	0	0
	0	0	0	0,0,1	0	0	0	0
Sharp-shinned hawk	0	0,2,0	0	1,0,0	1,0,0	0,1,0	0	0
	0	0	0	0	0	0	0	0
Stellar's jay	0	0	0	0	0	0	0	0,0,1
	0	0	0	0	0	4,0,0	0	0
Swainson's thrush	31,29,16	0	0	0	0	9,3,3	0	3,3,3
	24,25,15	0	0,0,1	1,0,0	1,0,0	16,2,1	0	5,4,4
Tennessee warbler	0	0	0	0	0	0	0	0
	0,0,1	0	0	0	0	0	0	0
Townsend's solitaire	0	0	0	1,0,0	0	0	0	0
	0	0	0	0	0	0	0	0
Townsend's warbler	60,58,39	0	0	0	0	0,0,1	0	0,0,1
	37,48,32	0	1,0,0	0	0	3,2,1	0	0,2,2
Tree swallow	1,1,0	7,6,1	0	5,8,2	2,0,1	0,2,1	4,4,0	0
	0	11,0,0	0	0,3,1	2,0,6	2,0,3	2,3,0	0
Three-toed woodpecker	1,8,4	0	0	0	0	0,1,5	0	4,0,0
	1,2,2	0	0	0	0	0,0,3	0	0,0,2
Unidentified	0	1,0,1	0,1,0	2,0,0	1,1,1	0	0	0,2,0
	0	1,0,1	1,1,0	0,0,1	0,1,0	0	1,0,0	0
Varied thrush	15,3,8	0	1,0,0	0	0	2,0,0	0	1,0,0
	7,0,1	0	0	0	0	0	0	0
Warbling vireo	1,1,1	6,0,0	0	0	0	0,0,1	0	1,1,0
	3,0,0	5,0,0	0	0	1,0,0	6,0,0	0	0
White-crowned sparrow	0	0	2,0,0	4,0,0	0	2,0,0	1,1,1	0
	0	3,6,3	1,0,0	0,0,1	1,0,4	0,0,1	0	0
Western flycatcher	0	0	0	0	0	0	0	0
	0,0,3	0	0	0	0	0	0	0
Western tanager	0	0	0	0	0	0	0	2,0,0
	0	0	0	0	0	0	0	0
Wilson's warbler	14,22,9	2,26,0	5,1,1	10,1,10	8,1,1	19,12,26	1,1,1	16,7,27
	16,3,14	26,33,2	10,4,6	11,2,9	11,24,10	35,23,39	10,6,10	23,22,41
Winter wren	15,2,5	0	0	0	0	0	0	0
	12,7,11	0	0	0	0	0,4,0	0	0
Western wood-pewee	0,0,3	0	0	1,1,0	0	4,0,0	1,0,0	6,0,1
	0	0	0	0	0	4,0,1	0	1,0,1
Yellow-bellied flycatcher	0	0	0	0	0	0	1,0,0	0
	0	0	0	0	0	0	0	0
Yellow warbler	0	0	0,0,1	0	0	0	0	0
	0	0	0	0	0	0	0	0
Yellow-rumped warbler	24,24,46	2,9,0	8,4,2	10,5,8	3,0,1	37,5,8	4,5,2	22,7,20
	17,33,30	16,2,7	4,11,8	5,15,4	13,3,9	26,16,20	11,14,17	18,11,12